U. S. DEPARTMENT OF AGRICULTURE,

OFFICE OF EXPERIMENT STATIONS.

A. C. TRUE, Director.

STUDIES

ON

BREAD AND BREAD MAKING.

BY

HARRY SNYDER, B. S., and L. A. VOORHEES, M. A.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., June 17, 1899.

SIR: I have the honor to transmit herewith a report of investigations on bread and bread making at the University of Minnesota in 1897 and 1898, by Prof. Harry Snyder, B. S., of the College of Agriculture of the University of Minnesota, and on losses in the process of making bread, by L. A. Voorhees, M. A., chief chemist of the New Jersey State Agricultural Experiment Station.

These investigations form a part of the nutrition investigations in charge of this Office, and were conducted under the supervision of Prof. W. O. Atwater, special agent in charge, in accordance with instructions given by the Director of this Office.

The investigations herewith reported belong to a series of inquiries into the nutritive value, digestibility, and economy of cereals, cereal products, and foods prepared from them. The effects of cooking are also taken into account. Progress reports of some of these studies have already been made, and the articles herewith submitted are of the same nature. On some points the results and conclusions are necessarily tentative and may be more or less modified by further investigations now in progress.

The reports are transmitted with the recommendation that they be published as Bulletin 67 of this Office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

STUDIES ON BREAD AND BREAD MAKING.

STUDIES ON BREAD AND BREAD MAKING AT THE UNIVERSITY OF MINNESOTA IN 1897 AND 1898.

By Harry Snyder, B. S.,
Chemist, Agricultural Experiment Station, and Professor of Chemistry, College of Agriculture, University of Minnesota.

INTRODUCTION.

The investigations which are reported in this bulletin have extended over two years, 1897 and 1898. The general purpose has been to study (1) the effect on the flour of the processes employed in bread making, that is, the action of ferments and heat, and the importance of these changes in household economy and in the manufacture of bread on a large scale; (2) the digestibility of bread from different sorts of flour, and (3) in connection with this work to study the chemical composition as related to the cost of bread and flour for sale in Minneapolis.

COMPOSITION OF SAMPLES OF MINNESOTA BREAD AND FLOUR AS RELATED TO THEIR COST.

The studies of the composition of bread were similar to those made at New Brunswick, N. J.,[1] and Pittsburg, Pa.[2] An extended study of the composition and cost of bread, biscuits or crackers, rolls, cakes, macaroni, and similar products for sale in Washington, D. C., has recently been reported by the Division of Chemistry of this Department in connection with an extended study of cereals and cereal products.[3]

In the investigations carried on at the Minnesota College of Agriculture a number of samples of bread and flour were purchased in Minnesota in the open market and analyzed. In several cases bread was made at the college. The usual analytical methods were followed.[4] The cost of the bread and flour was recorded when possible, with a view to learning whether the cost of bread was in proportion to the cost of the ingredients from which it was made. The further object was to see

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 52.

[3] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1319.

[4] U. S. Dept. Agr., Division of Chemistry Bul. 46.

whether the various sorts of bread differed materially in composition, and to learn whether Minnesota bread was, generally speaking, the same in composition and cost as that for sale in other parts of the United States. A description of the samples analyzed at the Minnesota Station follows:

DESCRIPTION OF SAMPLES OF BREAD AND FLOUR.

No. 1. Baker's white bread of average quality.

2. White bread, "homemade." Made at the Minnesota Agricultural College kitchen from second-grade or baker's flour.

3. White bread, "homemade." Made at the Minnesota Agricultural College kitchen from first-grade or patent flour.

4. Graham bread, "homemade." Made at the Minnesota Agricultural College kitchen. This bread was not made from pure graham, but from a mixed flour.

5. Corn bread, "homemade," from the Minnesota Agricultural College kitchen. This was made of yellow Indian corn meal.

6. Graham bread from bakery. An average loaf of so-called graham bread. It was, however, made from an imitation of graham flour.

7. Rye bread from a bakery. This was an average rye bread.

8. White bread from bakery. An average bread made from roller-process flour.

9. Whole-wheat bread. This was made from genuine whole-wheat flour, a considerable amount of sugar being used.

10. Whole-wheat bread. This was made from the same flour as No. 9, but no sugar was used.

11. White bread from "first clearings," ground by the Washburn and Crosby Milling Company.

12. White bread from first patent flour made by Washburn and Crosby Milling Company.

13. Whole-wheat bread. This is an ordinary baker's whole-wheat bread.

14. Rye bread, "homemade."

15. Bread from "Roman" flour (whole wheat), "homemade."

16. Graham bread from the Minnesota Agricultural College kitchen. This was made from a so-called graham flour of unknown quality.

17. Corn bread. This was made at the Minnesota Agricultural College kitchen from white corn meal.

18. White bread, "homemade." This was made at the Minnesota Agricultural College kitchen from "Pillsbury's Best" flour.

19. Biscuit. These were made at the Minnesota Agricultural College kitchen.

20. White bread from high-grade patent, Consolidated Milling Company's flour. This is a type of very white bread.

21. White bread from regular patent, Consolidated Milling Company's flour.

22. Bread from first baker's flour from Consolidated Milling Company. This was a lower grade flour than that used in sample No. 21.

23. Bread made from low-grade flour. This was a lower grade flour than that used in sample No. 22 and known commercially as "Red Dog grade."

24. White bread, "homemade," from Cottage Grove. This was made from first-grade patent flour and was a good type of homemade bread.

25. Graham bread from Cottage Grove, "homemade."

26. Baker's white bread, "homemade" grade. An ordinary baker's bread as sold in market.

27. White bread, cheapest grade.

28. Baker's whole-wheat bread. This was evidently not a genuine whole-wheat bread.

29. Homemade bread. This was made from first-grade patent flour. The dough was mixed with water and no fat was added.
30. "Pillsbury's Best" flour.
31. Bread made from sample No. 30 ("Pillsbury's Best" flour).
32. Graham flour. This was known to be a true graham flour.
33. Bread, "homemade," from No. 32 (graham flour).
34. White patent flour.
35. Bread made from No. 34 (white flour).
36. White bread, "homemade," from whitest grade of flour.

COMPOSITION OF BREAD AND FLOUR.

The composition of the different samples of bread and flour is given in the table below. When the bread was purchased at a bakery the cost is included. In the case of homemade bread, where possible the cost of the bread was estimated. The weight of a loaf is also given. The table includes also the average composition of the different sorts of bread analyzed at the Minnesota Station, at New Brunswick, Pittsburg, and Washington.

Composition and cost of bread and flour.

Reference number.	Description of food material.	Price of loaf.	Weight of loaf.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
		Cents.	*Grams.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	Bakers' white bread	5	480	34.20	9.875	1.49	53.77	0.665
2	White bread, "homemade," from bakers' flour	$1\frac{1}{2}$	$453\frac{6}{10}$	32.80	10.437	.74	55.37	.654
3	White bread, "homemade" grade	$1\frac{3}{4}$	$453\frac{6}{10}$	30.00	9.125	3.05	56.988	.837
4	"Graham bread" from flour which was not a true graham	$2\frac{1}{4}$	$453\frac{6}{10}$	35.10	8.370	1.66	53.77	1.10
5	Corn bread, "homemade," from yellow Indian corn meal	1	$453\frac{6}{10}$	35.80	7.187	5.66	50.313	1.04
6	Bakers' graham bread	5	478	32.50	8.875	2.48	55.344	.801
7	Bakers' rye bread	5	471	36.70	8.187	.506	54.017	.59
8	Bakers' white bread, patent roller-process flour	5	482	33.40	9.781	2.14	54.101	.578
9	Whole-wheat bread made with sugar	$1\frac{3}{4}$	$453\frac{6}{10}$	33.90	11.062	.473	53.621	.944
10	Whole-wheat bread made without sugar	$1\frac{3}{4}$	$453\frac{6}{10}$	34.20	11.25	.56	53.075	.915
11	White bread made from first "clearing"	......	491	33.90	10.937	1.27	53.055	.838
12	White bread from first patent flour	......	488	32.70	9.785	.63	56.265	.620
13	Bakers' whole-wheat bread	5	495	32.30	11.687	.652	54.423	.938
14	Rye bread, "homemade"	$2\frac{1}{4}$	$453\frac{6}{10}$	38.20	9.187	1.09	50.523	1.00
15	Bread from "Roman flour," "homemade"	3	$453\frac{6}{10}$	40.50	10.25	.898	47.572	.78
16	Graham bread, Minnesota College of Agriculture, "homemade"	$2\frac{1}{4}$	$453\frac{6}{10}$	31.70	10.25	3.78	53.17	1.10
17	Corn bread made from white corn meal	1	$453\frac{6}{10}$	48.00	6.531	2.88	41.819	.77
18	White bread, "homemade," from "Pillsbury's Best" flour	$1\frac{3}{4}$	$453\frac{6}{10}$	31.20	9.687	2.41	56.243	.46
19	Biscuit, Minnesota College of Agriculture, "homemade"	$1\frac{3}{4}$	$453\frac{6}{10}$	30.70	10.219	1.95	56.601	.53
20	White bread from high-grade patent flour	......	492	32.90	8.75	1.37	56.47	.51
21	White bread from regular patent flour	......	496	34.10	9.03	1.28	54.91	.68
22	Bread from bakers' flour	......	492	39.10	10.645	1.21	48.205	.84
23	Bread from "Red Dog" grade of flour	......	490	40.70	12.593	1.14	44.277	1.29
24	White bread, "homemade"	$1\frac{7}{8}$	$453\frac{6}{10}$	27.70	9.438	.503	61.459	.90
25	Graham bread, "homemade"	$2\frac{1}{2}$	$453\frac{6}{10}$	27.80	10.687	1.44	58.923	1.15
26	Baker's bread, "homemade" grade	$2\frac{1}{3}$	484	28.40	8.72	1.95	60.38	.55
27	Baker's white bread, cheapest grade	$2\frac{1}{2}$	488	31.65	9.25	2.07	56.327	.703
28	Baker's whole-wheat bread, not a genuine whole-wheat bread	5	492	35.50	8.06	.578	54.868	.994
29	"Homemade" bread from first-grade patent flour, made with water, but no fat	$1\frac{3}{4}$	$453\frac{6}{10}$	33.716	9.375	.660	55.667	.582
30	"Pillsbury's Best" flour	......	....	10.853	13.062	1.327	74.33	.428
31	"Homemade" bread from "Pillsbury's Best" (30)	$1\frac{3}{4}$	$453\frac{6}{10}$	36.70	10.125	.758	51.969	.448
32	Graham flour, known to be a pure sample	$2\frac{1}{2}$	$453\frac{6}{10}$	10.825	14.812	2.988	69.897	1.478
33	"Homemade" bread from sample No. 32	......	....	34.244	9.375	3.251	51.854	1.276

Composition and cost of bread and flour—Continued.

Reference number.	Description of food material.	Price of loaf.	Weight of loaf.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
		Cents.	*Grams.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
34	White patent flour	(1)		12.362	12.437	1.62	73.075	.506
35	White bread made from sample No. 34			32.80	8.875	3.529	54.175	.621
36	"Homemade" white bread from whitest grade of flour	2	453$\frac{6}{10}$	34.13	8.937	1.089	55.193	.651
	Bread made from patent and baker's grades of flour (average of 17 Minnesota samples)			32.90	9.57	1.28	55.44	.81
	Bread made from graham and whole-wheat flours of known purity (average of 6 Minnesota samples)			33.82	10.55	1.21	53.41	1.01
	Bread made from imitation whole-wheat flour (average of 2 Minnesota samples)			33.10	9.16	2.64	54.06	1.04
	Corn bread (average of 2 Minnesota samples)			41.90	6.86	4.27	46.07	.90
	Rye bread (average of 2 Minnesota samples)			37.40	8.69	.80	52.31	.80
	Average of 77 samples of bread analyzed at New Brunswick[2]			35.81	9.30	1.26	52.55	1.08
	Average of 10 samples of bread analyzed at Pittsburg[3]			32.6	10.8	.5	54.8	1.3
	Vienna bread, average of 10 samples analyzed at Washington[4]			38.71	8.87	1.06	50.17	1.19
	"Homemade" bread, average of 2 samples analyzed at Washington[4]			33.02	7.94	1.95	56.04	1.05
	Graham bread, average of 9 samples analyzed at Washington[4]			34.80	8.93	2.03	51.65	1.59
	Rye bread, average of 7 samples analyzed at Washington[4]			33.42	8.63	.66	55.45	1.84
	Quaker bread, average of 3 samples analyzed at Washington[4]			36.16	7.78	1.14	53.86	1.06
	Miscellaneous bread, average of 9 samples analyzed at Washington[4]			34.41	7.60	1.48	55.02	1.49

[1] $4 per barrel.
[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 35, p. 10.
[3] U. S. Dept. Agr., Office of Experiment Stations Bul. 52, p. 44.
[4] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1319.

SUMMARY.

The following general deductions were drawn from an examination of the different samples of Minnesota bread:

(1) Seventeen samples of Minnesota bread made from the patent and bakers' grades of flour gave an average of 9.57 per cent protein, the maximum and minimum amounts being 10.93 and 8.72, respectively.

(2) The high percentage of fat in some of the bread samples is caused by the large amounts of lard and other fats used for shortening purposes. From some of the samples of bread appreciably less fat was obtained in the dry matter than was present in the dry matter of the flour from which the bread was made. This apparent loss of fat is considered in another article in this bulletin (p. 37).

(3) The bread made from the imitation whole-wheat flours contained less protein than bread made from the patent and bakers' grades of flour, while the bread made from true whole-wheat flours—that is, flours from which none of the germ or other parts of the wheat had been removed—contained about 1 per cent more protein than bread made from ordinary flour. No conclusions, however, as to the relative nutri-

tive value of whole wheat and ordinary flours can be drawn from the figures given.

(4) The rye bread contained slightly less protein than ordinary wheat bread, while the corn bread contained less than the rye.

(5) The average "pound loaf" of fresh bread as sold by bakers weighed on an average about 480 grams, equivalent to about 1 pound 1 ounce.

(6) A pound loaf of bread can be made from about three quarters of a pound of flour, about 25 per cent of water being added to the flour during the process of bread making. With some flours 5 to 10 per cent more water can be absorbed, making a greater weight of bread product from a given weight of flour. This additional weight is water and not nutrients. At 2 cents per pound for flour, it is estimated that a pound loaf of bread can be made, not counting fuel and labor, for about 2 cents, a half cent being allowed for shortening and yeast.

LOSS OF DRY MATTER IN BREAD MAKING.

In bread making the action of the yeast and heat results in: (1) The fermentation of the carbohydrates and the production of carbon dioxid and alcohol; (2) the production of soluble carbohydrates, as dextrin, from insoluble forms, as starch; (3) the production of lactic and other acids; (4) the formation of other volatile carbon compounds; (5) a change in the solubility of the proteid compounds; (6) the formation of amid and ammonium compounds from soluble proteids, and (7) the partial oxidation of the fat. In addition to these changes there are undoubtedly many others which take place. Inasmuch as many of the compounds formed during the fermentation process are either gases or are volatile at the temperature of baking, appreciable losses of dry matter must necessarily take place in bread making. These losses are usually considered as amounting to about 2 per cent of the flour used.[1] In exceptional cases, as in prolonged fermentation, under favorable conditions the losses may amount to 8 per cent or more.[2]

The losses, as determined by various investigators, are as follows: Voorhees,[3] 4.3 per cent; Heeren,[4] 1.57 per cent; Fehling,[4] 4.21 per cent; Graeger,[4] 2.14 per cent; Jago,[5] 2.5 per cent; Dauglish,[6] 3 to 6 per cent. The loss of dry matter in bread making is such an important matter, inasmuch as it has direct bearing upon the food value of bread, that it was deemed advisable to make a study of the subject in order to determine the exact nature and extent of the losses.

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[1] U. S. Dept. Agr., Farmers' Bul. 23.

[2] Minnesota Sta. Bul. 54, p. 48.

[3] U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

[4] König, Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., 1889, vol. 2, p. 614.

[5] Jago, The Science and Art of Bread Making, p. 361.

[6] Ibid.

LOSS OF CARBON AS CARBON DIOXID.

A number of preliminary experiments were made in order to determine the best way of collecting the gas given off during the fermentation and baking processes. A baking tin was finally used, constructed in such a way that all the carbon-dioxid gas given off during the entire process could be collected and determined. The carbon dioxid was removed from all of the air admitted to the baking tin during both the rising and baking operations. A slow current of air was drawn through the baking tin, and all carbon dioxid produced by the action of the yeast and given off during the bread making was removed from the air that came from the baking tin. All of the flour, yeast, and water used in the several bakings were weighed, and all of the carbon dioxid produced in each operation was also collected and weighed.

Description of apparatus.—The baking tin *d* was provided with a tight-fitting cover, which was cemented to the pan with plaster-of-Paris cement.[1] The baking tin was connected with two block-tin pipes.

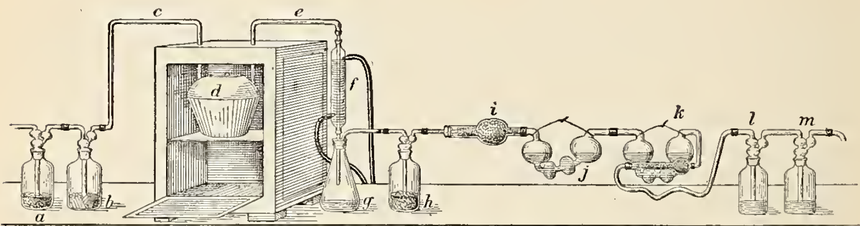

FIG. 1.—Apparatus for determining carbon dioxid evolved during baking of bread.

Through pipe *c* air was admitted. The air before being admitted into the baking tin first passed through the wash bottles *a* and *b*, containing, respectively, potassium hydrate and soda-lime, materials used to absorb the carbon dioxid of the air. The air admitted into the baking tin through pipe *c* escaped through pipe *e*, which was connected with a glass condenser. The carbon dioxid given off during the process was carried with the air which was aspirated through *e*. In addition to air and carbon dioxid, alcohol and all other volatile products formed during the fermentation and baking operations were given off through *e*. The condenser was connected with an Erlenmeyer flask *g*, which received the alcohol, water, and condensed products. From the flask *g* the carbon dioxid passed through a wash bottle *h* and a tube *i*, both containing calcium chlorid, to remove the last traces of moisture

[1] This was selected as the most convenient means of cementing the cover to the bread pan. It is known that carbon dioxid will pass through plaster of Paris. It is believed, however, that in these experiments no material amount was lost in this way. The cover fitted the bread pan so closely that there was very little space between them; furthermore, the plaster of Paris was quite thick in proportion to its width, and no gas was allowed to accumulate in the tin or to exert any pressure upon the cement.

before the gas passed on into the absorption tubes *j* and *k*, where the carbon dioxid combined with potassium hydrate and was retained. The tubes *j* and *k* were of large size, each capable of absorbing 10 grams of carbon dioxid. The tubes were weighed before and after each operation. The increase in weight showed the amount of carbon dioxid absorbed. The potash bulb *k* was connected with wash bottles *l* and *m*, containing limewater, which was used to determine whether all of the carbon dioxid given off was absorbed by the potash bulbs. The tube passing out of *m* was connected with a suction pump. A current of air was drawn through the apparatus at the rate of about three bubbles per second. The apparatus used in the bread-making experiments was tested in the following way: Between wash bottle *b* and baking tin *d* a small carbon-dioxid generating flask was placed, containing 0.4025 gram of calcium carbonate, which gave by analysis 43.1 per cent CO_2, and 0.1715 gram of carbon dioxid was recovered from that generated in the baking apparatus from the calcium carbonate used. The theoretical amount called for was 0.1735 gram, the amount recovered being 98.8 per cent of the amount taken.

The apparatus used during the rising process was somewhat simplified (fig. 2). The tube *e* connected directly with an absorption tube *f* containing calcium chlorid, and only one potash bulb *g* was used.

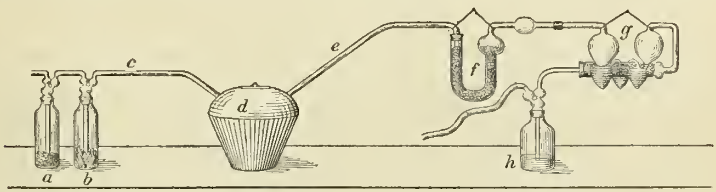

FIG. 2.—Apparatus for determining carbon dioxid evolved during fermentation of bread.

Before kneading the bread all the air in the baking tin was drawn off; the cover was then removed, and the bread was kneaded down gently. The cover was replaced and the liberated carbon dioxid was removed by drawing a current of air through the tin. The carbon dioxid being a heavy gas, it is assumed that it remained in the tin when the cover was temporarily removed. After the first gentle kneading and the removal of the liberated gas, the cover was removed and the bread was kneaded down without removing from the tin. The bread produced in this way was a little darker in color and was coarser grained than that made in the ordinary way.

In all, eight experiments were made. In the preliminary work flour from both spring wheat and winter wheat was used. As there seemed to be but little difference in the losses from either kind of flour, it was thought best to confine the work to one grade of flour, so that the results would be more comparable. (The patent roller-process spring-wheat flour used contained a much higher percentage of gliadin than the flour (No. 32) used in the bread experiment carried on in 1897 (see p. 22).

The flour used had the following composition:

Composition of the patent roller-process spring-wheat flour used.

	Per cent.
Water	11.86
Protein (N × 5.7)	11.96
Fat	1.33
Soluble carbohydrates	1.58
Starch[1]	67.22
Ash	.41
Undetermined	5.64

In four of the trials the bread was made by the short-fermentation process, while in four other trials the long-fermentation process was used. These methods are as follows:

Short-fermentation method.—A stiff dough is made of the flour, water, and yeast. It is thoroughly kneaded and is then allowed to rise until it doubles its bulk, when it is again kneaded thoroughly. After rising a second time it is baked. In the short-fermentation process a large quantity of yeast is used, and the time of fermentation is only about two and a half hours. The baking is completed in about four or four and one-eighth hours after the bread is first started to rise.

Prolonged fermentation.—A batter is made of the flour, yeast, and water, which is allowed to ferment ten or fifteen hours, usually over night. More flour is then added, the dough is kneaded until smooth, and then allowed to rise, and treated in the same way as in the first method. In the prolonged fermentation method less yeast is used than in the short process, and the fermentation is carried on for a longer time. In the prolonged fermentation trials the temperature during the first four or five hours was about 70° F. During the night the temperature of the room for four or five hours was about 50° F. In the trials reported in 1897[2] the temperature during the entire process was kept at a little over 70° F.

In the experiments reported no milk or fat was used in making the bread. The dough was made from a weighed quantity (about 400 grams) of flour. After kneading the dough, the amount of flour unused was deducted from the original amount. This gave the amount actually used for the bread. During baking the gas was given off rapidly at first, and then more slowly toward the close of the operation. The water and alcohol were given off almost entirely at the close of the operation. On account of the necessarily peculiar structure of the baking tin it was impossible to remove the bread without cutting it into small pieces. Hence the weight of the bread produced is not included in the table, as there was necessarily some slight loss. The tempera-

[1] Determined by the diastase method.

[2] Minnesota Sta. Bul. 54, p. 48.

ture of baking was about 400° F., which is just a little below the temperature at which the block-tin pipes would melt. The bread was baked in an ordinary oven over a gasoline stove.

The results of the test are shown in the following table:

Loss of carbon dioxid in bread.

	Materials.			Carbon dioxid.		
	Flour.	Yeast.	Water.	Produced during rising.	Produced during baking.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Short fermentation process:						
Bread No. 1	390	6.4	210	0.24	3.89	1.06
Bread No. 2	420	6.4	230	.29	3.86	1.09
Bread No. 3	390	6.2	230	.18	3.68	1.00
Bread No. 4[1]	385	6.1	230	[1].85	[1]5.35	[1]1.67
Average				.24	3.81	1.05
Long-fermentation process:						
Bread No. 5	410	3.30	230	1.025	2.41	.80
Bread No. 6	440	3.15	230	1.410	2.66	.90
Bread No. 7	400	3.25	230	1.100	2.58	.96
Bread No. 8	390	3.07	230	1.540	2.47	1.03
Average				1.300	2.52	.95

[1] Abnormal fermentation—omitted from averages.

From the table it appears that, on an average, about 1 per cent of carbon dioxid is produced and given off during bread making.

In the short-fermentation process the amount of carbon dioxid given off while baking exceeded by over 50 per cent the amount given off during the baking in the long-fermentation process.

In the long-fermentation process the amount of carbon dioxid given off while rising was about five times the amount given off during the same stage in the short-fermentation process.

Under the conditions in which these experiments were made the total loss of carbon dioxid was nearly the same for the two processes. In the case of abnormal fermentations, or prolonged fermentations at a higher temperature and under more favorable conditions, the loss of carbon dioxid may materially exceed 1 per cent.

In good bread making by either process the amount of carbon dioxid lost need not exceed 1 per cent.

LOSS OF CARBON IN THE FORM OF ALCOHOL.

During the fermentation process in bread making the production of carbon dioxid is accompanied by the production of alcohol. Theoretically, for every part of carbon dioxid gas formed there is also produced 1.04 parts of alcohol. It is generally supposed that during baking the alcohol is entirely given off. The theoretical amounts of alcohol formed during bread making in the above experiments, when calculated on the basis of the carbon dioxid evolved, would be as follows, in the short-fermentation process: (1) 1.10 per cent alcohol; (2) 1.13 per cent alcohol; (3) 1.04 per cent alcohol. Similar values for the long-fermentation process would be: (5) 0.83 per cent alcohol; (6) 0.94 per cent alcohol; (7) 1 per cent alcohol; (8) 1.07 per cent alcohol; general average, 1.02.

On an average there is about 1 per cent by weight of alcohol produced when bread is made. It serves a useful purpose. In baking the alcohol is volatilized and the vapor aids the carbon dioxid in expanding the dough, thus making the bread more porous. About 40 cubic centimeters of condensed products were obtained in flask *g*. When the contents of the flask was submitted to fractional distillation, no distillate was obtained until a temperature of nearly 90° was reached, showing that the alcohol was exceedingly dilute.

In several instances the amount of alcohol in the liquid recovered in the flask was determined by oxidation with chromic acid. The method followed was essentially that described by Blair[1] for the determination of carbon in iron by oxidation with chromic and sulphuric acids. Two additional U-tubes containing sulphuric acid were, however, added to the train to collect and retain acetic acid formed from incomplete oxidation of the alcohol. The acid in only one of the tubes was discolored. The contents of both tubes were then added to the generating flask and the oxidation completed. It is believed that this method secured practically all of the alcohol, as no unoxidized organic products could be detected.

The actual amounts of alcohol obtained by distillation and by the chromic acid method were less than half the theoretical amounts called for. Some of the alcohol had undoubtedly undergone chemical changes resulting in the formation of such bodies as organic acids. In one experiment 10 cubic centimeters of 95 per cent alcohol was added to the other ingredients in making the bread. The alcohol had no apparent effect upon the action of the yeast; the bread was in every way normal, except that an odor of alcohol was perceptible.

Samples of normal fresh bread were subjected to distillation and to other tests, but the distillate did not contain enough alcohol to give an appreciable reaction.

In general it may be said that there is on an average about 1 per cent of alcohol formed during bread making, and no appreciable amount of this alcohol is left in the bread.

LOSS OF CARBON AS OTHER VOLATILE COMPOUNDS.

In addition to carbon dioxid and alcohol, there is a small amount of carbon lost in other forms, such as volatile acids. If a bulb containing sulphuric acid is placed between the calcium chlorid tube *i* and the potash bulb *j* (fig. 1) it will be found that the sulphuric acid becomes dark colored, indicating that volatile compounds have been absorbed. The carbon thus obtained is probably formed from volatile organic acids. In four trials the carbon given off during baking, in the form

[1] Iron Analysis, p. 149.

of volatile organic matter, was determined. The volatile products, after removing the alcohol, were absorbed by sulphuric acid, and the carbon dioxid, to which they were equivalent, was determined by oxidation with chromic acid.[1] The amount of carbon dioxid thus obtained was: In sample No. 9, 0.10 per cent; No. 10, 0.14 per cent; No. 11, 0.07 per cent; and No. 12, 0.10 per cent. The result shows that some volatile organic matter containing carbon, either as hydrocarbons, volatile acids, or in other forms was given off during baking, and that the carbon thus obtained was equivalent to about 0.10 per cent of carbon dioxid.

PRODUCTION OF SOLUBLE CARBOHYDRATES IN BREAD MAKING.

In wheat flour the carbohydrates are present mainly in the form of insoluble starch. There are, however, a number of other insoluble carbohydrates and small amounts of soluble carbohydrates, chiefly in the form of dextrin, with a small amount of sucrose.

A summary of the more important investigations on the insoluble and soluble carbohydrates of wheat, together with the results of a number of studies on this subject, has been recently reported by the Division of Chemistry of this Department.[2] From experiments of the Division of Chemistry and the best available data, normal air-dried wheat is said to contain insoluble carbohydrates as follows:

Average amount of insoluble carbohydrates in air-dried wheat.

	Per cent.
Starch	54.0–59.0
Free pentosans	3.5– 4.5
Lignin and its allies	2.0– 2.5
Cellulose	1.6– 2.1
Total insoluble carbohydrates	61.1–68.1

The soluble carbohydrates of wheat investigated by the Division of Chemistry were invert sugar, sucrose, and dextrin or galactin. The amounts of these constituents found in wheat and a number of wheat products are as follows:

Invert sugar, sucrose, and dextrin or galactin in wheat and wheat products.

Name.	Invert sugar.	Sucrose.	Dextrin.
	Per cent.	*Per cent.*	*Per cent.*
Wheat	0.027	0.330	0.160
Wheat flour	.014	.101	.190
Graham flour	.038	.382	.210
Self-raising wheat flours	.000	.056	.080
Miscellaneous wheat flours	.003	.098	.130
Common market wheat flours	.021	.288	.210
Bakers' and family flours	.027	.190	.220
Patent wheat flours	.002	.085	.200

[1] Blair, Iron Analysis, p. 149.

[2] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1192.

In addition to the soluble carbohydrates mentioned above, small amounts of raffinose have been reported by several investigators in wheat germs. Wheat germ contains more sucrose than any other of the wheat products, and the amount of soluble carbohydrates in wheat flour depends largely upon the proportion of germ present.

A sample of flour (No. 2) used in the experiments at the Minnesota Station to determine the extent to which starch is changed to soluble forms in bread making contained 1.62 per cent of soluble carbohydrates calculated as dextrin.

In addition to the production of alcohol and carbon-dioxid gas by fermentation, the action of the yeast and heat results in the production of soluble carbohydrates from insoluble forms. During the baking process the heat changes some starch to dextrin. In the process of bread making this results in both the consumption and production of soluble carbohydrates. The extent to which insoluble starch is changed to soluble forms in bread making is a subject which does not appear to have been extensively investigated. König[1] states that fine wheat bread contains 4.02 per cent sugar and coarse bread 2.08 per cent. The term sugar, however, is not defined.

The extent to which soluble carbohydrates are either consumed or produced during bread making is an important matter, because flour contains on an average 65 per cent or more of starch, and any change affecting the starch has a direct effect upon both the composition and value of the bread produced. In order to determine the extent to which soluble carbohydrates are produced, six experiments were made. In three experiments the bread was made by the short-fermentation process and in three other experiments by the long-fermentation process.

No attempt was made to separate and determine the different carbohydrates, as sucrose, dextrose, and dextrin. The separation of the soluble carbohydrates in flour, as a group, is a difficult matter. Flour contains soluble ferments which change some of the insoluble starch to soluble forms whenever flour is left in contact with water for any length of time.

The method used was as follows: Twenty grams of flour and 200 cubic centimeters of water were placed in a flask and thoroughly shaken. The water was left in contact with the flour for two hours and was then decanted into a filter of double thickness. A clear yellowish tinged filtrate was obtained, 100 cubic centimeters of which was submitted to hydrolysis and the dextrose determined in the usual way. For the bread 100 grams and 500 cubic centimeters of water were used. Concordant results could not be obtained with dilute solutions.

The details of each experiment are given in the following table, from which it will be observed that while the flour contains 1.62 per cent of

[1] Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., 1889, vol. 2, p. 617.

soluble carbohydrates the fresh bread produced from the flour contained from 3.2 to 4.3 per cent.

Soluble carbohydrates of bread.

	Weight of flour used.	Weight of bread produced.	Soluble carbohydrates in bread.	Soluble carbohydrates in bread.	Soluble carbohydrates in flour.
Short-fermentation process:	*Grams.*	*Grams.*	*Per cent.*	*Grams.*	*Grams.*
Bread No. 13	290	415	3.3	13.70	4.70
Bread No. 14	284	399	3.3	13.17	4.60
Bread No. 15	280	393	4.3	16.90	4.54
Long-fermentation process:					
Bread No. 16	325	426	3.2	13.63	5.26
Bread No. 17	325	435½	3.4	14.79	5.26
Bread No. 18	325	427	3.5	14.94	5.26

Notwithstanding the loss of carbohydrates caused by the production of alcohol and carbon dioxid, these fresh breads contained from 3.2 to 4.3 per cent of soluble carbohydrates. Allowing for average losses of carbohydrates by fermentation, not far from 6 to 8 per cent of the total insoluble starch originally present in the flour has been changed to soluble forms during the bread-making process. There are other changes which the starch has undergone which are not shown by chemical analysis. By the combined action of the ferments and heat the forms of many of the starch grains in bread are materially changed. When bread is extracted with alcohol and water to remove a part of the proteids and the soluble carbohydrate bodies, the forms of the starch grains may be distinctly studied.

Many of the starch grains appear as if they had been partially digested, and many pieces of disintegrated starch granules are present. In some cases the outer layers of the starch grains appear as if they had been subjected to pressure and partially ruptured. Many of the smaller and medium-sized grains appear unaltered. These physical changes which the starch grains have undergone during the bread-making process doubtless render bread (when properly made) more susceptible to the action of solvents, as the digestive fluids.

The changes which the carbohydrates undergo in bread making may be briefly summarized. They are both physical and chemical. Not far from 6 to 8 per cent of the insoluble starch is changed to soluble forms, while the combined action of the ferments and heat ruptures a large portion of starch grains, rendering them more susceptible to further changes.

PRODUCTION OF ACIDS IN BREAD MAKING.

Wheat bread made with yeast gives an acid reaction. The amount of acid varies with the quality of the yeast, the flour, and the conditions which govern the fermentation or rising process. Bread[1] is said to

[1] Jago, The Science and Art of Bread Making, p. 366.

contain lactic, acetic, and occasionally butyric acids. The characteristic acid of wheat flour has, however, never been determined. For convenience the acidity is expressed as percentage amounts of lactic acid.

All wheat flours contain variable amounts of acid bodies. Calculated as lactic acid, the acidity of normal flour usually ranges between 0.09 and 0.15 per cent. In old and in musty flours the acidity may exceed 0.5 per cent.

For the determination of the acidity of flour, in the experiments which follow, 20 grams of flour and 200 cubic centimeters of water were placed in a flask and shaken vigorously. After the flour had been in contact with the water for an hour the solution was filtered and 50 cubic centimeters titrated with a tenth normal solution of potassium hydrate, using phenolphthalein as an indicator. Flour does not readily give up its acid to solvents.

The acidity of a number of samples of wheat flour and wheat products was determined with the following results, the acid being estimated as lactic acid:

Acidity of flour and other wheat products.

	Samples analyzed in 1897.	Per cent.
No. 1	Roller-process patent flour	0.09
No. 2	Spring wheat patent flour	.09
No. 3	Winter wheat patent flour	.09
No. 4	Roller-process flour, second grade	.12
No. 5	Musty flour	.46
No. 6	Red Dog flour	.54
No. 7	Wheat germ	.68

The acidity of the dough and of the bread of a number of samples made from the same flour was determined. The amount of acid (estimated as lactic acid) was determined in six samples of dough, six of fresh bread, and six samples of bread made by the short-fermentation process, which had been baked three days. The acid was also determined in three samples of sour-bread dough, five samples of fresh bread from the same dough, and in five samples of the bread which had been baked three days.

Acidity of dough and bread made in different ways.

	Short-fermentation process.						Sour-dough process.				
	Sample 1.	Sample 2.	Sample 3.	Sample 4.	Sample 5.	Sample 6.	Sample 1.	Sample 2.	Sample 3.	Sample 4.	Sample 5.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Dough	0.36	0.36	0.36	0.33	0.40	0.33	0.60	0.58	0.60	......	......
Fresh bread	.18	.20	.22	.12	.14	.16	.38	.36	.38	0.38	0.40
Bread three days after baking	.22	.27	.30	.20	.25	.27	.58	.44	.57	.59	.61

In the trials, the acidity of the dough made by the short-fermentation process was between 0.3 and 0.4 per cent. In sour dough, the acidity was about 0.5 per cent. The bread contains a lower percentage of acid than the dough. This appears to be due in part to the volatilization of some of the acid during baking, and also to the combination of the acid with other bodies in the bread (see p. 24).

In the first stages of fermentation the acidity of dough was found to be much less than in the last stages. When the alcoholic fermentation became less active, the acidity of the dough increased. The acidity of the dough also varies with the quality of the yeast. The acidity of both the bread and dough in the long-fermentation process was found to be greater than in the short-fermentation process. The results were calculated as lactic acid. Three samples were analyzed. No. 13 contained 0.12 per cent, No. 14 0.12 per cent, and No. 15 0.12 per cent of lactic acid. These samples were made by the short-fermentation process. Of the samples made by the long-fermentation process No. 16 contained 0.28 per cent, No. 17 0.30 per cent, and No. 18 0.32 per cent of lactic acid.

The presence of milk, and also the kind of milk, was found to have an appreciable effect upon the acid content of the bread, as may be observed from the following table, which shows the acidity of bread made with milk and the average acidity of bread made with water:

Acidity of bread made in various ways.

	Bread made with fresh milk.	Bread made with skim milk.	Bread made with sterilized skim milk.	Bread made with water (short fermentation).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Bread, fresh	0.09	0.135	0.09	0.17
Bread, 1 day old	.18	.18	.12	....
Bread, 2 days old	.16	.21	.13	....
Bread, 3 days old	.16	.21	.15	.25

The effect which acids have upon the food value of the bread is difficult to estimate. The loss in food value by the production of acids when the bread contains only about 0.2 per cent is not serious. In sour bread the losses by the formation of acids are much greater.

BEHAVIOR OF THE PROTEIDS OF WHEAT FLOUR IN BREAD MAKING.

In bread making the changes which the proteids undergo appear to have been less extensively studied than the changes which affect the carbohydrates. The part which the proteids take, however, seems of equal importance.

According to Osborne[1] the proteids of wheat are (1) an albumin soluble in water and coagulable by heat; (2) a globulin soluble in dilute

[1] Amer. Chem. Jour., 15 (1893), pp. 468–471.

salt solutions and coagulable by heat; (3) a proteose body soluble in water and not coagulable by heat; (4) gliadin soluble in dilute alcohol; and (5) glutenin which is insoluble in water, salt solutions, or dilute alcohol. The last two are present in larger quantity than the others, and together form the gluten of wheat and of flour.

Wheat gluten is composed of 60 to 70 per cent gliadin and 30 to 40 per cent glutenin. The gliadin constitutes the binding material of the flour and enables the dough to retain the gas and to become light when the bread is made. A flour that contains an excess of gliadin is soft and sticky, while one deficient in this material is lacking in power of expansion. The glutenin is the material to which the gliadin adheres and thus prevents the dough from becoming too soft and sticky. In hard wheat flours the gluten is believed to be composed of gliadin and glutenin in the ratio of about 65 to 35,[1] while in the flours from soft wheats the ratio is 70 to 30.

A flour similar to the one used in these experiments and from the same source contained the following percentages of the several proteids:

Proteids in wheat flour.

	Per cent.
Albumin	0.3
Globulin	.9
Proteose body	.2
Gliadin	6.8
Glutenin	4.5
Total	12.7

The gluten of flour, independent of ferment action, possesses, when baked, a power of expansion varying with the quality of the flour from which the gluten is obtained. An apparatus for testing the expansive power of gluten of flour has recently been devised by C. M. Foster, of Minneapolis, and has been described in a publication[2] of the Division of Chemistry of this Department. As a general rule the better the baking qualities of the flour the greater the power of expansion. The illustration (fig. 3) shows the expansive power, as measured by Foster's apparatus, of the gluten from two samples of flour containing nearly the same percentage of total protein compounds but different percentages of gluten.

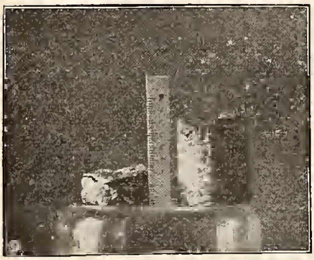

Fig. 3.—Gluten from two samples of flour.

The quality of gluten determines very largely the quality of the bread which is produced. Two samples of flour may contain about the same relative amounts of carbohydrates and proteid compounds, and

[1] Minnesota Sta. Bul. 54, p. 42.

[2] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1272.

FIG. 1.—Bread from normal flour and from mixtures of normal and extracted flours: A, normal flour; B, flour with about one-half of the gliadin extracted; C, one-half normal and one-half gliadin-extracted flour.

FIG. 2.—Bread from normal flour and from mixtures of normal and corn flours: A, normal flour; B, normal flour and 20 per cent corn flour; C, normal flour and 10 per cent corn flour.

BREAD FROM NORMAL FLOUR, FROM MIXTURES OF NORMAL AND EXTRACTED FLOURS, AND FROM MIXTURES OF NORMAL AND CORN FLOURS.

have about the same amount of gas produced during fermentation, and yet produce bread of entirely different physical properties because of the difference in the gluten in the two flours. The two samples from which the glutens shown in fig. 3 were prepared are flours which produce bread of entirely different physical properties. The percentage of carbohydrate and protein compounds in the two samples are nearly the same, but the glutens are entirely different, as the illustration indicates.

As stated above, the quality of the bread is determined very largely by the relative proportion of gliadin and glutenin in the gluten. In order to produce the best quality of bread the gliadin and glutenin must be present in the right proportion to form a balanced gluten. This fact can best be illustrated by noting the effect produced by removing a part or all of the gliadin. The gliadin from a sample of high-grade patent flour was removed by extraction with alcohol, and when bread was made from the gliadin-extracted flour the dough was not sticky. It felt like putty and broke in the same way. The yeast caused the mass to expand a little when first placed in the oven, then the top of the loaf began to break apart, and there was a decrease in size. The result was a loaf of less than half the size of that made from the same weight of normal flour. On the other hand, when the water-soluble proteids were extracted from normal flour the bread was normal in appearance. When the globulin was extracted the bread was also normal. The bread, however, produced from flour which had been extracted with water, and with dilute salt solutions, was nearly tasteless, probably due to the removal of the soluble carbohydrates and other fermentation products. (See Pl. I.)

The removal of a part of the gliadin also resulted in producing nearly the same effect as the removal of all the gliadin. A sample of flour containing 1.95 per cent total nitrogen and 1.23 per cent gliadin-nitrogen was partially extracted with alcohol. The extracted flour contained 1.41 per cent total nitrogen. The bread produced from this flour was very similar to that produced when all of the gliadin was extracted. When half normal flour and half of the partially extracted flour were mixed the bread product was only slightly improved. Three trials at different times gave substantially the same results. From these experiments it is evident that any interference with the gliadin-glutenin ratio in flour has a marked influence upon the quality of the bread product. When the gliadin-glutenin ratio was left undisturbed a foreign proteid could be introduced without materially interfering with the rising of the bread. Bread made with 10 per cent corn flour and 90 per cent patent wheat flour had nearly the same coefficient of expansion as bread made from normal flour.

From these experiments it would appear that as long as the gliadin-glutenin ratio remains normal it is possible to reduce slightly the percentage amounts of these two proteids without materially influencing the expansion coefficient of the dough, but any material change of the gliadin-glutenin ratio materially influences the power of the dough to expand and produce a good quality of bread.

Inasmuch as the protein compounds are subject to changes during the bread-making process and any changes affecting the gluten proteids may affect the physical properties of the bread, it follows that the part which the proteids take in bread making is an important one. It was therefore studied in considerable detail.

In this investigation flour (No. 2) of the following composition was used: Water, 9.74 per cent; protein ($N \times 5.7$), 11.80 per cent; ether extract, 0.92 per cent; soluble carbohydrates, 1.62 per cent; starch,[1] 68.80 per cent; ash, 0.46 per cent; undetermined, 6.54 per cent, and acidity (as lactic acid), 0.12 per cent.

The plan followed was to determine the solubility of the nitrogen in the flour, in the dough, and in the bread, since during the process of bread making the proteids are acted upon by (1) ferments, (2) by acids produced during the fermentation, and (3) by heat. The question naturally suggests itself: To what extent does the combined action of these three agents affect the composition of the proteids?

The solubility of the nitrogenous compounds expressed in terms of nitrogen was as follows, the total nitrogen being 2.07 per cent: Water-soluble nitrogen (albumin, proteose, etc.), 0.32 per cent; salt-soluble nitrogen (globulin), 0.12 per cent; alcohol-soluble nitrogen (gliadin), 1.31 per cent.

The two proteids, gliadin and glutenin, are both soluble in dilute acid and alkaline solutions, gliadin being more soluble in acid than glutenin.

Independent of all ferment action, the proteids seem to be acted upon by the acid bodies produced during the fermentation. There appears to be a partial union between the acid and the proteid bodies. The fact that flour can, in some way, absorb acid bodies was demonstrated in the following way: Ten cubic centimeters of a dilute solution of lactic acid (containing 0.549 gram) was introduced into a flask containing 10 grams of flour and 90 cubic centimeters of water. After being in contact with the flour for an hour only 0.441 gram of lactic acid could be obtained by titration, showing that 10 grams of flour had absorbed 0.108 gram of the acid. That this absorption was somehow connected with the proteid bodies was shown by separating the gluten from 10 grams of flour and placing it in a flask with 10 cubic centimeters of dilute lactic acid (containing 0.549 gram). Only 0.443 gram of acid was recovered. Hydrochloric and other acids are absorbed in a similar way. In order to determine the extent to which the acids in the dough act upon the proteids, weighed quantities of flour were

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[1] Estimated by the Lindet method.

subjected to the action of dilute solutions (0.22 per cent) of lactic acid. The results are as follows:

Effect of lactic acid upon proteids of flour.

	Lactic acid used.	Nitrogen of proteids rendered soluble.
	Per cent.	*Per cent.*
Flour No. 1	0.22	0.43
Flour No. 2	.44	.48
Flour No. 3	.55	1.12

With a dilute lactic-acid solution proteid equal to 0.43 per cent of nitrogen, in excess of water-soluble proteid, was dissolved.

When a given amount of acid was added to a definite weight of gluten, not all of the acid could be recovered by subsequent titration with a standard alkali solution. The acid, however, rendered some of the proteid more soluble. These facts would indicate that the acid and the proteid had formed a soluble compound, and that the acid was held in such a firm state of combination that it could not subsequently be combined with an alkali. A similar reaction takes place in the manufacture of "sweet-curd" cheese. The milk before it is coagulated contains a much higher percentage of acid than the whey. The small amount of acid combined with the milk proteids can not be recovered with an alkali. The observation of Nasse,[1] confirmed by Schützenberger, that a certain fraction of the nitrogen of proteids is in less stable forms of combination than the rest, offers in part an explanation of the behavior of gluten proteids in acid solutions.[2]

The acid of 0.55 per cent strength, which corresponded to the strength of the acid found in the sour dough (flour No. 3), dissolved 1.12 per cent nitrogen. Under ordinary conditions the acids formed during bread making, independent of ferment action, are capable of dissolving about 0.5 per cent nitrogen.

The amounts of water-soluble nitrogen found in doughs of various degrees of acidity are shown in the following table:

Soluble nitrogen in doughs of different acidity.

	Acidity.	Soluble nitrogen.
	Per cent.	*Per cent.*
Dough No. 1	0.25	0.50
Dough No. 2	.20	.41
Dough No. 3	.40	.52
Dough No. 4	.60	1.20

[1] Watts, Dictionary of Chemistry, Proteids, Vol. IV, p. 328.

[2] Since this bulletin has been prepared for the press, Osborne (Jour. Amer. Chem. Soc., 21 (1899), p. 486) has published an article "Definite compounds of protein bodies," in which he states, page 493, that "what has heretofore been regarded as 'native' protein substances are, in fact, protein bodies combined to acids, so that preparations as usually obtained have been mixtures of simpler salts of these bodies." This statement is in harmony with the facts reported in this bulletin.

It is to be observed that the amount of soluble nitrogen in doughs increases with the acidity of the dough, and that the solvent action of the acids accounts for nearly all the soluble nitrogen. This would indicate that the ferment bodies have not directly acted upon the proteids to any appreciable extent but that the acid products of fermentation have rendered some of the proteids soluble. In the most acid dough the amount of soluble nitrogen was found to be 1.20 per cent.

The fact that the proteids of the dough are of a different nature from the proteids of flour can be shown by placing about 30 grams of acid dough in a linen bag and attempting to obtain the gluten by washing. Only about a third as much is obtained as from the same amount of flour, showing that the gluten of the dough has undergone marked changes.

When bread is baked the heat changes the solubility of some of the proteids. The albumin and the globulin are both coagulated at the temperatures reached in baking, and are changed from water-soluble and salt-soluble to insoluble forms.

The water-soluble nitrogen in six samples of bread was determined. In three of the breads, samples 1, 2, and 3, made by the short-fermentation process, there was a low acidity, while in three other samples, 4, 5, and 6, made by the long-fermentation process, the acidity was high. The alcohol-soluble or gliadin nitrogen was also determined. The results are given, on the basis of the dry matter, in the following table:

Soluble nitrogen in bread.

	Acidity.	Total nitrogen.	Water-soluble nitrogen.	Alcohol-soluble nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Short-fermentation process:				
Bread No. 1	0.13	2.30	0.11	....
Bread No. 2	.13	2.26	.10	1.31
Bread No. 3	.13	2.30	.11	1.26
Long-fermentation process:				
Bread No. 4	.60	2.30	.50	.77
Bread No. 5	.60	2.26	.55	.75
Bread No. 6	.61	2.28	.50	....

Breads made from doughs of low acidity contain only a small amount of water-soluble nitrogen. But little nitrogen is rendered soluble in the dough, and the albumin and globulin are coagulated during the baking.

When a high acidity is reached in the dough the amount of water-soluble nitrogen produced in the bread is increased. This is due apparently to the solvent action of the acid produced during the rising process.

From the table it appears that the gliadin is probably the proteid which is rendered soluble, as there is a decrease of alcohol-soluble nitrogen and a proportional increase of water-soluble nitrogen.

It is a well-known fact that in order to produce good bread from some flours a longer fermentation is necessary than from other flours. The longer fermentation undoubtedly reduces the gliadin content, so that the proportions between the gliadin and the glutenin are better suited for bread making.

It is generally considered that yeast is used in bread making simply for the purpose of producing gas to expand the dough. In some flours, however, yeast has an additional action, namely, to produce acid bodies which combine with the gliadin to form acid proteids, so that the ratio between the remaining gliadin and glutenin becomes more or less favorable for the production of a good quality of dough. Hence the same method of bread making does not produce the same results with all flours because of the differences in the composition of the gluten in the various flours.

LOSS OF NITROGEN IN BREAD MAKING.

Proteids constitute about 97 per cent of the total nitrogenous material of flour. In addition, flour contains nitrogen in other forms, as amid nitrogen. The amount of amid nitrogen is small, usually ranging from 0.02 to 0.08 per cent. The amid compounds do not constitute so stable a group as the proteids. In bread making the more stable protein compounds undergo only a limited change in solubility, as discussed in the preceding section; the amid compounds may, however, be converted into ammonia and lost.

The two factors which affect the loss of nitrogen in bread making are (1) the amount of nonproteid nitrogen in the flour, and (2) the nature of the fermentation. When bread is made from flour containing only a small amount of amid nitrogen, and the fermentation is of such a nature that amid compounds are not formed from soluble proteids, the amount of nitrogen lost is small.

There are at least two ways by which the amount of nitrogen lost during bread making may be determined: (1) by analyzing the flour and bread, to determine the amount of nitrogen obtained in bread made from a known weight of flour, and (2) by analyzing the gaseous products evolved during the process of bread making. In this work both methods were employed. Two series of investigations were made, one in 1897 and one in 1898. The work of the first year was of a preliminary nature. In 1897 bread was made from flour which contained 2.09 per cent nitrogen; in 1898 bread was made from flour which contained 2.07 per cent of total nitrogen, and 0.3 per cent amid nitrogen. The first method of procedure was as follows: A portion of flour (300 to 400 grams), more than sufficient for the required amount of bread, was weighed. The bread was made by the short-fermentation process, mechanical losses of flour being avoided as much as possible. The amount of unused flour was weighed and deducted from the original amount. The same amount of yeast and water was used for each loaf.

In the following table is shown the weight of materials used and of the bread obtained in 1897, when the short process of fermentation was employed:

Weight of materials used and bread made by short-fermentation process in 1897.

	Flour.	Water.	Yeast.	Bread.
	Grams.	*Cc.*	*Grams.*	*Grams.*
Bread No. 1	353.57	230	6.85	512.76
Bread No. 3	368.34	230	6.27	520.70
Bread No. 5	322.28	230	6.57	445.10

The dry matter and nitrogen in the material and bread, and the actual and percentage losses are shown in the following table:

Dry matter and nitrogen in materials used and bread made by short-fermentation process in 1897.

	Dry matter.						Nitrogen.					
	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.
	Gr.	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*P. ct.*	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*P. ct.*
Bread No. 1	315.20	2.36	317.56	312.94	4.62	1.48	7.39	0.14	7.53	7.23	0.30	3.94
Bread No. 3	328.36	2.16	330.52	322.05	4.75	1.43	7.69	.13	7.82	7.81	.01	.13
Bread No. 5	287.30	2.26	289.56	286.90	2.66	.92	6.74	.13	6.87	6.76	.11	1.60

When bread was made by the long-fermentation process in 1897 the weight of the materials used and of the bread made was as follows:

Weights of materials used and bread made by long-fermentation process in 1897.

	Flour.	Water.	Yeast.	Bread.
	Grams.	*Cc.*	*Grams.*	*Grams.*
Bread No. 2	378.20	230	1.68	490.1
Bread No. 4	390.67	230	2.66	525.7
Bread No. 6	435.82	230	2.45	553.6
Bread No. 7	415.7	230	2.35	566.1

The dry matter and nitrogen in the materials used and the bread made, as well as the actual and percentage losses of dry matter and nitrogen, are shown in the following table:

Dry matter and nitrogen in materials used and bread made by long-fermentation process in 1897.

	Dry matter.						Nitrogen.					
	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.
	Gr.	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*P. ct.*	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*P. ct.*
Bread No. 2	337.15	0.59	337.74	310.28	27.46	8.14[1]	7.90	0.03	7.93	7.057	0.880	11.09[1]
Bread No. 4	348.27	.92	349.02	313.30	35.70	10.23[1]	8.17	.05	8.22	7.730	.488	5.94
Bread No. 6	388.52	.85	389.37	362.50	26.87	6.90	9.11	.05	9.16	8.304	.856	9.29[1]
Bread No. 7	370.58	.81	371.39	355.34	16.05	5.93	8.69	.05	8.74	8.208	.532	6.016

[1] Abnormal losses.

In 1898 practically this same method was followed. The bread was weighed when fresh and was again weighed after standing eighteen hours. It was then prepared for analysis.

The weight of the ingredients used in making the bread, the weight of the dough and bread, and the percentage of water in the bread are shown in the following table:

Weight of ingredients and dough and percentage of water in bread made by short-fermentation process in 1898.

	Materials used.			Dough when mixed.	Dough when kneaded.	Fresh bread.	Bread 18 hours old.	Water in bread 18 hours old.
	Flour.	Water.	Yeast.					
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Bread No. 8	290	172	4.5	456.9	456	425.3	415	37.23
Bread No. 9	284	172	4.5	450.5	445	408.4	398.8	36.16
Bread No. 10	280	172	4 5	444.7	442.2	402	392.8	36.78

After the second weighing each loaf was cut into halves and the two portions analyzed separately by different analysts. A quarter of a loaf was used for the moisture determination, and it was found that concordant results could not be obtained by crumbing the bread and using a weighed quantity of the mixed crumbs for the determination of moisture. The amount of moisture present in different parts of a loaf of bread is extremely varied, as the following determinations show: Water in crust, 22.29 per cent; water in crumb, 40.65 per cent; water in different parts of the crumb, 38.77, 42.95, and 42.01 per cent.

Nitrogen determinations were made with the fresh bread, and the dried material after it had been pulverized and thoroughly mixed. The most satisfactory results were obtained by using the dry material. Unless otherwise stated, all the results were obtained from the analysis of such material.

The composition of the bread (water-free substance) made by the short-fermentation process in 1898 was as follows:

Composition of bread made by short-fermentation process in 1898.

	Dry matter.					
	Protein (N×5.7).	Ether extract.	Soluble carbohydrates.	Insoluble carbohydrates.	Ash.	Acidity.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bread No. 8	13.11	0.37	5.25	80.70	0.44	0.13
Bread No. 9	13.11	.44	5.25	80.60	.47	.13
Bread No. 10	12.88	.42	6.80	79.29	.48	.13

The yeast had the following composition: Water, 64.53 per cent; ether extract, 0.44 per cent; total nitrogen, 1.65 per cent; carbohydrates, 23.26 per cent, and ash, 1.46 per cent.

The dry matter in the materials and in the bread made from them, as well as the actual and percentage loss of dry matter, are shown in the following table:

Total dry matter in materials and bread made by short-fermentation process in 1898.

	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.	Average loss.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*	*Per cent.*
Bread No. 8	261.7	1.6	263.3	260.5	2.8	1.07	
Bread No. 9	256.3	1.6	257.9	254.6	3.3	1.28	1.58
Bread No. 10	252.7	1.6	254.3	248.3	6.0	2.38	

The nitrogen in the materials and bread made from them, together with the actual and percentage loss of nitrogen, are shown in the following table:

Total nitrogen in materials and bread made by short-fermentation process in 1898.

	Flour.	Yeast.	Total.	Bread.	Loss.	Average loss.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Gram.*	*Per cent.*
Bread No. 8	6	0.07	6.07	5.99	0.08	
Bread No. 9	5.87	.07	5.94	5.88	.06	1.45
Bread No. 10	5.80	.07	5.87	5.75	.12	

Under the conditions of these experiments there was an average loss of 1.58 per cent of total dry matter and 1.45 per cent of the total nitrogen. The difference between the amount of nitrogen in the bread and that in the flour and yeast is so small that it might well be questioned whether this loss is not within the limits of error of ordinary chemical work. In order to check the results, the gases evolved during bread making were analyzed. The general arrangement of the apparatus used was much the same as that employed in collecting the carbon dioxid (see p. 12). A U-tube containing sulphuric acid was substituted for the potash bulbs. After the gas evolved had passed through the apparatus, the contents of the flask *g* and of the U-tube were transferred to a Kjeldahl flask and the nitrogen determined in the usual way. Four determinations were made. The amount of nitrogen given off from 300 grams of flour was found to be small, about 0.02 per cent. When the bread was dried in the drying oven a larger amount of nitrogen was given off than during the baking process. Twenty-five one-hundredths gram of bread when dried yielded from 0.01 to 0.02 per cent nitrogen. It is to be observed that while the two methods do not absolutely agree as to the amount of nitrogen lost, there is, however, a slight loss observable in each case. When bread is properly made, this loss of nitrogen need not seriously affect its nutritive value.

To obtain additional information on this matter determinations of the nitrogen in the crust and crumb were made with a sample of each. The complete analysis of the samples is also reported. On the basis of dry matter the amount of nitrogen found was practically the same in both.

Composition of crust and crumb.

	Water.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Nitrogen in dry matter.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crust	22.29	11.43	0.60	65.30	0.38	2.35
Crumb	40.65	8.87	.49	49.67	.32	2.39

While the amount of nitrogen lost when bread is properly made is small, the amount lost when bread is not properly made may materially exceed the figures given above.

In order to determine to what extent losses may occur under abnormal conditions, or what are frequently usual conditions, bread was made without any special care, except to avoid mechanical losses. The long-fermentation process was followed, the same flour being used as in the tests by the short-fermentation process. A batter was made in the afternoon and the bread raising completed the next day about noon. A strongly acid dough resulted. The weight of flour and of the bread made, together with its content of water, are given in the following table:

Weight of material and bread, and of water in bread, made by long-fermentation process in 1898.

	Materials.			Fresh bread.	Water in fresh bread.
	Flour.	Yeast.	Water.		
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Bread No. 11	325	2.2	172	437.2	35.03
Bread No. 12	325	2.2	172	435.5	36.68
Bread No. 13	325	2.2	172	427	35

Composition of bread made by long-fermentation process in 1898.

	Dry matter.					
	Protein (N × 5.7).	Ether extract.	Soluble carbohydrates.	Insoluble carbohydrates.	Ash.	Acidity.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bread No. 11	13.11	0.1	4.93	80.8	0.49	0.57
Bread No. 12	12.88	.3	5.25	80.46	.52	.59
Bread No. 13	13	.17	5.49	80.21	.52	.61

The loss of dry matter and nitrogen in the bread made is shown in the following table:

Dry matter and nitrogen in materials used and bread made by the long-fermentation process in 1898.

	Dry matter.					Nitrogen.				
	In flour.	In yeast.	Total.	In bread.	Loss.	In flour.	In yeast.	Total.	In bread.	Loss.
	Grams.	*Gram.*	*Grams.*	*Grams.*	*Per ct.*	*Grams.*	*Gram.*	*Grams.*	*Grams.*	*Per ct.*
Bread No. 11	293.3	0.8	294.1	276.8	5.88	6.73	0.03	6.76	6.37	5.77
Bread No. 12	293.3	.8	294.1	275.6	6.29	6.73	.03	6.76	6.22	7.98
Bread No. 13	293.3	.8	294.1	277.5	5.64	6.73	.03	6.76	6.32	6.5

It will be observed that by excessive fermentation resulting in the production of acid dough, there may be a loss of 5 per cent or more of dry matter. When some of the same flour was made into bread by less fermentation and with more care, the loss of dry matter was only 1.58 per cent, as noted above.

These figures indicate that in good bread making it is possible to reduce the losses caused by fermentation to about 3 pounds of flour per barrel. When less care is exercised the loss may be as high as 12 pounds of flour per barrel.

Von Bibra[1] states that there is less nitrogen in the crust of bread than there is in the crumb. According to this author the crumb of wheat bread contained 1.498 per cent nitrogen and the crust 1.363 per cent, while the crumb of rye bread contains 1.476 per cent and the crust 1.293 per cent.

In making bread, milk or lard is usually added to the dough. The effect upon the composition of the bread may be observed from the following table, which shows the composition of bread made with and without these ingredients:

Composition of flour, and bread made from it in different ways.

	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Flour	10.11	12.47	0.86	76.09	0.47
Bread made with water	36.12	9.46	.40	53.70	.32
Bread made with lard	37.70	9.27	1.02	51.70	.31
Bread made with skim milk	36.02	10.57	.48	52.63	.30

CHANGES IN THE SOLUBILITY OF FAT DURING BREAD MAKING.

It has frequently been observed that the ether extract of bread made of flour and water only is much lower than the ether extract in the flour from which it was made.[2] In flour No. 2 there was 0.96 per cent of ether extract. In none of the breads made from this flour was there more than 0.44 per cent of ether extract obtained (calculated on the dry matter basis). That is, of the total ether extract in the flour, not more than half was obtained as ether extract in the bread. Before extraction with ether the bread was dried at 100° in hydrogen.

In flour No. 2 the fat obtained was light colored, while that from the bread was decidedly dark colored and separated in the form of globules. During the process of bread making and drying there had evidently been some change affecting the composition of the fat, rendering it less soluble. The iodin absorption number of the fat from the flour and from the bread was determined. That of fat from flour was 101.4 and that of fat from bread, 60.4.

[1] König, Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., 1889, vol. 2, p. 614.

[2] U. S. Dept. Agr., Office of Experiment Stations Buls. 35 and 52.

SUMMARY.

The results of these investigations may be summarized as follows:

(1) In ordinary bread making about 1 per cent of carbon dioxid was given off during the rising and baking processes and a little more than 1 per cent of alcohol was formed. There was also given off during baking a small amount of volatile acid products.

(2) The determination of the volatile products given off during bread making showed a total loss of 0.74 per cent of the total carbon in the flour, which is equivalent to about 1.68 per cent of starch.

(3) When special care was taken in bread making, the analyses of the flour and the bread showed an average loss of 1.58 per cent of the total dry matter of the flour.

(4) The analyses of the gases produced, and of the flour and bread, indicate that for good bread making the total losses need not exceed 2 per cent of the flour used, and that it is possible to reduce the losses to 1.1 per cent.

(5) The amount of alcohol recovered in bread making was found to be less than the theoretical amount corresponding to the carbon dioxid produced. This discrepancy is not due to alcohol remaining in the loaf, since no appreciable amounts of alcohol were recovered from fresh bread. When alcohol was used in making bread the action of the yeast was apparently normal.

(6) In bread making the starch undergoes both physical and chemical changes. From 3 to 4 per cent of soluble carbohydrates were found in the bread, indicating that less than 8 per cent of the total starch was changed from insoluble to soluble forms. The physical changes which many of the starch granules undergo are marked. Some are partially disintegrated, while others are ruptured.

(7) Normal flour contains a small amount of acid. During bread making variable amounts of acid was produced by the action of the yeast. A part of the acid formed appears to unite with the proteids. In acid doughs the acid renders the proteids more soluble and changes the composition of the gluten.

(8) When bread is made from dough of low acidity there was less water-soluble nitrogen in the bread than in the flour, because of the coagulation of the albumin and globulin during baking. In bread made from doughs of high acidity the amount of water-soluble nitrogen was increased. This is due to the action of the acid on the insoluble proteids. The gliadin is rendered soluble, which changes the gliadin-glutenin ratio of the bread.

(9) The power of expansion which the gluten of a flour possesses determines very largely the physical properties of the bread. Some glutens possess an expansive power four or five times greater than others.

In general it may be said that in good bread making the loss of dry matter and of nitrogen need not exceed 1.6 per cent of the total amounts in the flour. In poor bread making the losses may exceed 6 per cent. In good bread making the losses are equivalent to about 3 pounds per barrel of flour, while with poor bread making the losses may exceed 12 pounds per barrel.

DIGESTIBILITY OF BREAD.

Two experiments on the digestibility of bread were made with a healthy man, a university student, about 22 years old. He had been accustomed to ordinary farm labor. During the experimental periods the exercise consisted of a daily walk of 4 miles. In the first experiment bread made from patent roller-process flour ground from Scotch Fife (a spring wheat) was eaten, and in the second, bread made from the bakers' grade of flour from the same wheat was used. In milling wheat by the patent-roller process the finest grade flour is the flour first removed; the product next obtained is the bakers' grade. It is ground nearly as fine as the patent flour, and differs from it mainly in the physical qualities of the gluten. The bread used in the tests was made by the quick-fermentation process described on page 14, with milk, butter, and salt in addition to the yeast and flour. In both tests eggs and butter were eaten in addition to the bread. Each test covered two days and practically the same amounts of bread, butter, and eggs were consumed daily. The usual experimental methods were followed. The feces were separated by means of charcoal.[1] The composition of the two sorts of flour, the bread made from them, and of the butter and eggs, is shown in the following table:

Composition of flour, bread, eggs, and butter.

	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Patent roller-process flour	12.36	12.44	1.62	73.07	0.51
Bread from patent roller-process flour	32,80	9.06	3.53	53.99	.62
Bakers' grade flour	8.01	15.50	2.22	73.52	.75
Bread from bakers' grade flour	38.25	10.81	2.13	47.79	1.02
Eggs	74.22	15.21	9.88		.92
Butter	10.98		86.12		

The food consumed in the two days of the first experimental period was as follows: First day, 672 grams patent flour bread; 5 eggs (net weight, 242.3 grams); 84 grams butter. Second day, the same quantity of bread and butter, and 4 eggs (net weight, 201.1 grams). The feces weighed 274.5 grams. The ether extract of the feces was found to contain some nitrogen; this was believed to be nitrogen of metabolic products. However, since it was not possible to settle this point definitely, no correction was made for it in determining the coefficients of digestibility. The dry matter of the feces weighed 62 grams and had

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 21, p. 58.

the following percentage composition: Total ether extract, 19.57; nitrogen in ether extract, 0.42; protein, 28.94; carbohydrates, 36.99, and ash, 14.50. The constituents of the food consumed and of the feces and the coefficients of digestibility of the mixed diet are shown in the following table:

Digestibility of diet containing bread made from patent roller-process flour.

	Dry matter.	Protein.	Fat.	Carbohydrates.
	Grams.	*Grams.*	*Grams.*	*Grams.*
In 443.4 grams of eggs	114.3	67.4	43.8	
In 168 grams of butter	149.7		146.3	
In 1,344 grams of bread	853.9	121.76	37.3	725.6
Total	1,117.9	189.2	227.4	725.6
In 62 grams (dry) feces	62.0	17.9	12.1	22.9
Amount digested	1,055.9	171.3	215.3	702.7
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Coefficient of digestibility	94.4	90.5	94.7	96.9

On the first day of the second experimental period the ration was as follows: 652 grams bread, made from bakers' grade of flour; 218.6 grams eggs; and 84 grams butter. On the second day, 672 grams bread, 242.3 grams eggs, and 84 grams butter. The feces weighed 279 grams. The dry matter of the feces weighed 62.5 grams and had the following percentage composition: Total ether extract, 19.05; nitrogen in ether extract, 0.40; protein, 30.94; carbohydrates, 32.49, and ash 17.52. The constituents of the food and feces and the coefficients of digestibility of the different nutrients are shown in the following table:

Digestibility of diet containing bread made from bakers' grade flour.

	Dry matter.	Protein.	Fat.	Carbohydrates.
	Grams.	*Grams.*	*Grams.*	*Grams.*
In 1,324 grams bread	817.6	143.1	28.2	632.7
In 461 grams eggs	118.9	70.1	45.6	
In 168 grams butter	149.6		144.7	
Total	1,086.1	213.2	218.5	632.7
In feces	62.5	19.3	11.9	20.3
Amount digested	1,023.6	193.9	206.6	612.4
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Coefficient of digestibility	94.2	91.0	94.6	96.8

It will be seen that the coefficients of digestibility of the mixed diet in the two experimental periods were practically the same. Since practically the same amounts of eggs and butter were consumed in each period, and the only varying factor in the diet was the bread, it seems fair to assume that the two sorts of bread had the same digestibility. The experimental periods were of short duration, and the data are doubtless insufficient for general deductions. The experiments do, however, indicate that there is no marked difference in the digestibility of bread made from the two sorts of flour.

At the beginning of the first test the subject weighed 159 pounds, and at the close 159¾ pounds. His weight at the beginning of the second test was 164½ pounds, and at the close 165 pounds—that is, in each experimental period the weight remained practically constant.

During the first test 1,615.4 grams urine was excreted, containing 1.67 per cent nitrogen, and during the second test, 1,714 grams, containing 1.69 per cent of nitrogen. The daily income of nitrogen in the first test was 15.1 grams, the outgo in the urine 13.5 grams, and in the feces 1.4 grams—that is, there was a daily gain of 0.2 gram nitrogen. In the second test the daily income of nitrogen was 17.1, the outgo in the urine 14.5, and in the feces 1.5. The subject therefore gained 1.1 grams nitrogen per day.

Summing up the results of the tests, it may be said that, as far as can be judged from coefficients of digestibility, changes in weight of the subject, and balance of income and outgo of nitrogen, no differences were observed when bread made from fine patent roller-process flour and bread from first bakers' grade of flour made from the same wheat was consumed by a healthy man.

LOSSES IN THE PROCESS OF MAKING BREAD.

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INTRODUCTION.

When flour is made into bread, it is subjected to the action of ferments (yeast) and heat. It is well recognized that these agents produce changes in the constituents of the flour, but the character and extent of the changes are not definitely known. Blyth[1] describes bread making, and speaks of the changes which take place, as follows:

Wheaten bread is the flour of wheat made into a paste with water, and the paste is permeated by carbon dioxid either by adding yeast, which causes a true fermentation with the production of alcohol and carbon dioxid, or the carbon dioxid is added in solution in water to the paste, as in Daughlish's system. The explanation of the bread-making process is not thoroughly worked out in all its details, but the following theory agrees fairly well with what is witnessed: On adding yeast to the dough it is placed on one side at a suitable temperature and allowed to rise—that is, fermentation proceeds, and there is a continual evolution of gas; the starch in some degree becomes changed into sugar, which sugar is decomposed into carbon dioxid and alcohol. The gluten prevents or rather retards the escape of the carbon dioxid, and the tension of the warm gas expands little cells and gives to the bread its familiar light, spongy appearance. The alcohol mostly escapes. * * * The outside of the loaf when placed in the oven is raised to a temperature of from 210° to 212° C., but the crumb is seldom much above 100°. The crust is to some extent caramelized. * * * In the crust there is a partial destruction of the nitrogenous substance. Thus Von Bibra found that the crumb of wheaten bread contained 1.498 per cent of nitrogen and the crust 1.363 per cent. The crumb of rye bread contained 1.476 per cent of nitrogen and the crust 1.293 per cent. * * * The fatty matters are not, as far as is known, changed. The ash is not changed save by the minute proportion of yeast ash which is added to it, an addition quite inappreciable. Further, any salt added by the baker increases a little its weight, but the ordinary method of burning bread volatilizes very effectually chlorids of the alkalies, so that the ash of bread is still very small.

In a publication of the Division of Chemistry[2] of this Department, the following statements are made:

The loss of solid matter during the fermentation and baking of the bread is due to the conversion of part of the solid matter into volatile substances and their evapora-

[1] A. W. Blyth, "Foods: Their composition and analysis," ed. 1888, p. 171.
[2] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1317.

tion during the process of baking. The only substances which are changed in any appreciable degree by this process are the sugars which the flour may contain. It is evident, therefore, that the loss in no case can be greater than is due to the fermentation of the sugars. It is not probable that any large quantity of sugar will be formed from the starch during the fermentation process. * * *

It must be admitted, moreover, that not all of the sugar which is present in a flour is decomposed during the process of fermentation, unless the period of raising the bread be prolonged beyond usual limits. In addition to this, it must be considered that it is difficult in the process of baking to expel all the products of the fermentation. A portion of the carbon dioxid and of the alcohol will undoubtedly remain entangled in the meshes of the loaf. Even, therefore, allowing for the fact that a portion of the starch may be converted into sugar and undergo a partial fermentation, it is not to be expected that the total loss in weight in dry matter in the loaf itself will be greater than the amount of sugar originally present in the flour. Of course, it is understood if the loaf be ground and dried for the purpose of a chemical determination of loss that the whole of the alcohol and carbon dioxid will be driven off, but in the loaf as it comes from the oven or as it is brought upon the table such a complete evaporation of the volatile products of fermentation is not found. * * *

In addition to the many changes mentioned above as due to fermentation, certain changes in the constitution of the materials of flour are produced by the combined action of heat and water. These changes, of course, are produced in the maximum degree in the crust of the bread, whereas the temperature of boiling water in the interior of the bread acts less vigorously in its effects upon the chemical constituents of the flour. In respect to the proteid matters, it is certain that all of the proteids of the material will be rendered insoluble by the temperature to which they are subjected. The proteid matters in the crust of bread certainly undergo additional changes by reason of the high temperature to which they are subjected, the nature of which is not definitely known. The same is true of the fats or oils, which are oxidized to a certain extent by the action of the oxygen of the atmosphere at the high temperature to which the crust is subjected. It is probable, therefore, that a splitting up to some degree of the molecules of the glycerids composing the fat and oil takes place, especially in the crust of the loaf. In the interior of the loaf the carbohydrates probably undergo little change except a degradation of the starch grains and a slight tendency of the starch to be converted into dextrin. In the crust, however, in addition to those changes, there is a decided caramelization of the starchy particles, as is evidenced by the browning of the loaf.

Bakery experiments in 1895 and 1896.—In 1895 two experiments were conducted at a well-equipped bakery in New Brunswick[1] to study the relative cost of the nutrients in bread and in its raw materials, and also the changes which occur in converting the latter into the former. The results were unexpected. It was found in these experiments that not only was there little apparent loss of protein and of carbohydrates but that there was a considerable loss of ether extract. A similar experiment has recently been conducted by Miss Isabel Bevier, at Pittsburg, Pa., and with similar results.[2]

For convenience in comparison, the results of these experiments have

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 52.

been recalculated to a uniform basis of 100 grams of dry matter in the materials used, and are summarized in the following table:

Summary of experiments in bread making at bakeries in New Brunswick and Pittsburg.

	Dry matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
First New Brunswick experiment:						
Material used	100.00	13.03	3.52	81.37	2.08	465.87
Material recovered	97.95	13.15	1.52	81.64	1.64	444.95
Material lost (—) or gained (+)	—2.05	+.12	—2.00	+.27	—.44	—20.92
Second New Brunswick experiment:						
Material used	100.00	13.74	4.01	80.16	2.09	457.90
Material recovered	97.04	13.72	1.64	79.78	1.90	443.73
Material lost	2.96	.02	2.37	.38	.19	14.17
Pittsburg experiment:						
Material used	100.00	15.58	1.35	80.87	2.20	435.64
Material recovered	95.88	15.37	.39	78.31	1.81	412.06
Material lost	4.12	.21	.96	2.56	.39	23.58

It will be seen from the above table that all of the ash was not recovered. This was undoubtedly due entirely to the method followed in making the ash determinations. There was practically no loss of nitrogenous materials, since the experiments show only variations which are within the limits of experimental error.

In the case of the fat the full amount supplied by the raw materials was not recovered in the ether extract of the bread, the discrepancy being greater, absolutely, and less, relatively, in the New Brunswick experiments than in that at Pittsburg. This is probably due to the fact that in the former case much more fat (lard) was used in making the dough than in the latter. The results from the two experiments differ, however, in one important particular. In the experiments at New Brunswick, the entire loss in total dry matter was accounted for by the losses in fat and ash; in that conducted at Pittsburg there was in addition a loss which by our methods of analysis falls upon the carbohydrates, since the carbohydrates are estimated by difference, and include the sums of the discrepancies. This amounted to 62 per cent of the entire loss. In all cases the fuel value (heat of combustion) of the bread was considerably less than that of the materials. In our belief this tended rather to verify than disprove that an actual loss of fat occurs in the process of baking, and that the loss is much greater than was formerly supposed. In Miss Bevier's opinion "it would seem that either the fat is rendered partially insoluble in ether during the process of baking or that it has been volatilized. The fact that there is a very considerable loss in the fuel value of the materials in the bread, as compared with that of the raw ingredients before baking, indicates that the latter is the true explanation, for, if the fats had simply been rendered nonextractable their heat of combustion would probably have remained nearly unchanged, and there would be no such pronounced loss of heat values as is actually the case."

Laboratory experiments in 1897.—In order to study further the changes which take place in the fat when bread is made, laboratory experiments[1] were conducted in 1897 upon small quantities and with a close control. The process of making bread may be divided into four steps, viz, (1) making the dough, (2) adding the leavening, (3) adding the shortening, and (4) the baking. In addition, in order properly to prepare the sample of bread for analysis, a subsequent drying is necessary. The experiments were so planned, therefore, that the bread making was arrested at the termination of the various steps and the resulting product analyzed. They show, therefore, the analysis of flour under the following conditions:

(1) Unmanipulated.

(2) Subjected to a temperature of 70° C., this being the temperature necessary to dry a sample of bread for analysis.

(3) Made into dough and then prepared for analysis by careful drying.

(4) Made into dough, baked unleavened, and then prepared for analysis as before.

(5) Made into dough, leavened, and then prepared for analysis.

(6) Made into dough, leavened and baked, and prepared for analysis.

(7) Made into dough, leavened and shortened, and prepared for analysis.

(8) Made into dough, leavened, shortened and baked, and prepared for analysis.

The results of these tests may be briefly summarized as follows: The amounts of dry matter in the samples prepared by these methods were but slightly different from the amounts which, on the basis of analyses, it was calculated the raw materials would furnish, the differences occurring mainly in the baked samples, probably on account of the browning of the crust. The amount of ether extract, however, was diminished in every case when the flour had been wet—i. e., made into a paste—the loss running as high as 85 per cent of the total fat. Simply drying the flour at 70° C. did not affect the amount of ether extract seriously. In the case of the samples to which milk (shortening) had been added, the total ether extract recovered was less than was added in the milk alone, although it is generally assumed that milk fat is not affected by a temperature of 100° C. There was no uniform connection observed between the apparent loss of the fat (ether extract) or loss of dry matter and the deficiency in heat of combustion; and in no case where the apparent loss of fat was serious was the deficiency in fuel value sufficient to account for the apparent loss in fat.

The fact that practically all the dry matter was recovered would indicate that the fat was not lost, but was unextracted. It is well

[1] New Jersey Stas. Rpt. 1897, p. 98.

understood that in the case of linseed meal, corn meal, and other similar products protracted heating in air will hinder the extraction of fat. This is usually attributed to oxidation, and it is known that oxidation certainly takes place when an air-dry sample of such material is heated. As noted above, protracted heating of the air-dry flour at 70° C. had only a trifling effect upon the ether extract. This fact and the failure to recover all the milk fat suggested that it was not oxidation but occlusion which hindered the ether from exerting its solvent action. In this particular the conclusions drawn from the experiments at the bakeries seem to be contradicted by the laboratory experiments.

LOSS OF MATERIAL IN BREAD MAKING.

EXPERIMENTS IN 1898—METHODS FOLLOWED.

Further experiments along these lines were conducted during 1898 to test the results previously secured and to extend the investigations. The brand of flour selected was the same as that used in 1897. Twenty-five pounds was carefully mixed and distributed in 25 glass jars by transferring a large spoonful to each jar, thoroughly mixing the remainder, and again transferring a spoonful to each jar. This was repeated until all but about a pound had been placed in the jars. This small remainder was discarded. The jars were closed with perfectly fitting tops and new rubber rings. A composite sample for proximate analysis was made up of portions from jars 1, 6, 10, 15, 19, and 24, and in addition, to test the uniformity of the distribution, determinations of moisture, protein, ether extract, and ash were made in the contents of jars 3, 8, 12, and 21. The results were all very uniform, the composite sample being practically identical with the average of the others, as is shown by the following table:

Composition of samples of flour.

	Water.	Nitrogen.	Ether extract.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sample from jar 3	12.21	2.22	1.25	0.49
Sample from jar 8	12.19	2.25	1.24	.52
Sample from jar 12	12.20	2.20	1.25	.50
Sample from jar 21	12.20	2.20	1.31	.53
Average	12.20	2.22	1.26	.51
Composite sample from jars 1, 6, 10, 15, 19, and 24	12.20	2.22	1.27	.51

In order to avoid the complications which would ensue from fermentation due to the use of yeast, the leavening in the bread-making experiments was accomplished, as in the experiments in 1897, with a leavening powder, a mixture of sodium bicarbonate and potash alum being used. The moisture, ether extract, and nitrogen in these substances were determined, and also in the combination of the two after they had been wet and the reaction had taken place. They contained neither nitrogen nor ether soluble substance. The dry matter was also determined. Since this consisted of sodium and potassium sulphates and aluminum hydrate, and as no salt (NaCl) was added in making the bread or the mixtures, it was considered sufficiently accurate to assume the ash by calculation.

EFFECT OF HEAT ON MILK.

In making bread, milk was used to furnish fat, since it is believed milk fat is not sufficiently affected when exposed to the air at temperatures not exceeding 100° C. to be rendered nonextractable with ether. In order to verify this belief, portions of milk weighing 25 grams each were dried upon pumice stone in three ways: (1) in an air bath at 70° C, (2) in a water oven at about 100° in air, and (3) in a water oven at about 100° in a current of dry hydrogen. The dried samples were analyzed. The results of these analyses are shown in the following table, together with the calculated constituents of 25 grams of milk before drying:

Constituents of fresh milk and milk dried in various ways.

	Solids.	Ether extract.	Casein.
	Grams.	*Gram.*	*Gram.*
Milk (25 grams), fresh (calculated)	3.05	0.91	0.81
Milk (25 grams), dried at 70° C	2.93	.89	.83
Milk (25 grams), dried at 100° C	2.98	.89	.84
Milk (25 grams), dried at 100° C. in hydrogen	2.94	.90	.84

It will be seen that the milk, and especially its fat content, was not affected by the temperatures used in drying the samples or by the temperature which is generally assumed[1] to be that of the interior of the loaf during baking.

TESTS WITH BREAD MADE IN VARIOUS WAYS.

In making the bread care was taken to prevent any burning or indeed any undue browning of the crust during baking, and it is believed that the problem studied is not complicated by any loss from such a cause. The portions of flour and milk used in making the bread and the resulting products were weighed on a large balance, sensitive to 10 milligrams, while the leavening chemicals, on account of their small amount, were weighed on an analytical balance, sensitive to one-twentieth milligram. After the raw materials were weighed extreme care was taken to prevent accession or loss of moisture. Rubber stoppers were substituted for the glass stoppers of the sample bottles, as changes in moisture content have been detected in the past in fodder materials contained in bottles stoppered with glass. The weight of the samples

[1] See Wiley, "Principles and Practice of Agricultural Analysis," Vol. III, p. 543; see also quotations from Blyth at beginning of this article.

analyzed was also determined before and after grinding. Only slight variations were observed. They were undoubtedly those incidental to grinding and sifting the samples, etc.

For each experiment 100 grams of flour was used: the flour was submitted to the same manipulation as in the experiments made in 1897 (see p. 40). In addition in some of the experiments a water oven was used for drying the product obtained at various steps in the bread-making process. In some instances the materials were dried in an atmosphere of hydrogen in a water oven at 100°. In all cases the samples were dried in air unless hydrogen is specified. The analysis of the raw materials and the various products were made by the methods prescribed by the Association of Official Agricultural Chemists.[1] Since the ether extract is determined in the sample which is used for the determination of dry matter, those samples which were dried in air or in hydrogen were in reality submitted to two dryings—one previous to analysis and one during analysis.

The results of the tests are given in the following table, which shows the composition of the unmanipulated flour or flour and other raw materials and their composition after treatment in the various ways indicated:

Constituents of materials and bread made in various ways.

Experiment number.		Dry matter.	In dry matter.			
			Protein.	Ether extract.	Carbohydrates.	Ash.
		Grams.	Grams.	Grams.	Grams.	Grams.
	Bread made from flour and water only:					
1	Flour, unmanipulated (100 grams)	87.80	13.88	1.27	72.14	0.51
2	Flour dried in air at 70° C	87.45	13.88	1.27	71.79	.51
3	Flour dried in air at 100° C	87.59	13.69	.84	72.55	.51
4	Flour made into dough and dried in air at 70° C.	87.98	13.44	.63	73.40	.51
5	Bread baked and dried at 70° C	87.54	13.56	.28	73.19	.51
6	Bread baked and dried at 100° C	87.82	13.93	.38	73.00	.51
	Bread made with flour, leavening, and water:					
	Flour (100 grams)	87.80	13.88	1.27	72.14	.51
	Leavening chemicals (1.56 grams)	1.56	....	....	....	1.56
	Total (calculated)	89.36	13.88	1.27	72.14	2.07
7	Total by analysis	89.39	13.88	1.33	72.11	2.07
8	Materials dried in air at 70° C	89.71	13.56	1.23	72.85	2.07
9	Materials dried in air at 100° C	89.41	13.75	.55	73.04	2.07
10	Materials made into dough and dried in air at 70° C.	89.17	13.56	.47	73.07	2.07
11	Dough dried in air at 100° C	89.37	13.81	.48	73.01	2.07
12	Dough dried in hydrogen at 100° C	89.04	13.56	.32	73.09	2.07
13		89.01	13.63	.31	73.00	2.07
14	Bread baked and dried at 70° C	89.38	13.81	.29	73.21	2.07
15		89.76	13.44	.39	73.86	2.07
16	Bread baked and dried at 100° C	89.24	13.81	.31	73.05	2.07
17		89.38	13.44	.23	73.64	2.07
18	Bread baked and dried in hydrogen	88.82	13.50	.29	72.96	2.07
	Bread made with flour, leavening, and milk:					
	Flour (100 grams)	87.80	13.88	1.27	....	....
	Milk (104 grams)	12.70	3.32	3.73	....	....
	Leavening chemicals	3.12	....	....	....	....
	Total	103.62	17.20	5.00	....	....

[1] U. S. Dept. Agr., Division of Chemistry Bul. 46.

Constituents of materials and bread made in various ways—Continued.

Experiment number.		Dry matter.	In dry matter.			
			Protein.	Ether extract.	Carbohydrates.	Ash.
	Bread made with flour, leavening, and milk—Cont'd.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
19	Dough dried in air at 70° C	103.67	17.06	3.95	....	....
20	Dough dried in air at 100° C	103.87	16.81	3.42	....	....
21	Dough dried in hydrogen	102.59	17.00	2.76	....	....
22	Bread baked and dried at 70° C	103.33	16.94	3.17	....	....
23	Bread baked and dried in hydrogen	101.92	16.88	2.49	....	....
	Bread made with flour previously extracted with ether:					
	Flour (100 grams)	93.31	14.56	.11	....	....
	Milk (104 grams)	12.70	3.32	3.73	....	....
	Leavening chemicals	3.12	....	....	....	....
	Total	109.13	17.88	3.84	....	....
24	Dough dried in air at 70° C	109.42	17.88	3.23	....	....
25	Dough dried in air at 100° C	109.35	18.00	2.76	....	....
26	Dough dried in hydrogen	109.17	17.88	2.26	....	....
27	Bread baked and dried at 70° C	109.59	18.00	2.09	....	....
28	Bread baked and dried in hydrogen	108.42	18.00	2.22	....	....

In all the experiments it will be noticed that the loss of nitrogenous constituents was very small, the greatest variation being equivalent to a variation of about 0.1 per cent of nitrogen. This is within the limits of experimental error and confirms the conclusions from the bakery experiments previously reported. In the case of the carbohydrates also there were no apparent losses. Such losses were not expected, since yeast was not employed to leaven the bread. On the contrary, in almost every case there was an apparent gain, but, as the carbohydrates are determined by difference and include the sum of all the errors in the determinations of the other constituents, these gains are not necessarily significant. They are intimately related to variations in the dry matter and ether extract. The results with these constituents confirm previous work. Practically all the dry matter was recovered in almost every case, but in those experiments (Nos. 1–18), in which no fat was present except that supplied by the flour, the ether extract showed deficiencies when either a high temperature was employed to dry the raw material or when the materials had been wet in making into dough. These discrepancies ranged from 33 to 70 per cent of the total ether extract. In experiments Nos. 19–23, in which milk fat had been added in making the bread, the ether extract recovered in but one instance equaled the amount supplied in the milk alone. The apparent loss of fat, therefore, holds good for the animal fat added to the dough as well as to the vegetable fat present in the flour. This is well shown in experiments Nos. 24–28, which were made with flour which had been previously extracted with ether until practically free from fat. In these experiments also the added animal fat was not entirely recovered.

The following explanations have been suggested for this discrepancy in fat: (1) Oxidation, which prevents the extraction of the fat, causing it to be estimated with the carbohydrates; (2) volatilization, whereby the fat is actually lost, and (3) occlusion, with a result similar to oxidation.

Oxidation.—As has already been stated, it is well known that vegetable substances containing drying oils, such as linseed meal and corn meal, can not properly be dried, for analysis, in air previous to extraction with ether, for the fat will be oxidized and rendered partially insoluble. The water also can not be determined by drying in air, for the results will be too low or, what is the same thing, the dry matter, will be too high. These considerations lead to the method of drying samples in an atmosphere of hydrogen. If there is an oxidation of fat there should also be an increase in the dry matter recovered. As is shown in the experiments, there was in most cases very little gain in the dry matter, and in experiments Nos. 12, 13, 18, 21, 23, 26, and 28, where the materials were dried in hydrogen and the dry matter recovered was actually lower than when dried in air, there is as great a discrepancy in the fat as when the samples were dried in air. This indicates that a change of some sort has taken place, but the lower results secured do not necessarily indicate that the change has taken place in the fat. Furthermore, there is a loss of milk fat, which in some cases is considerable, notably in the samples which were dried in hydrogen. Judging by the experiments in which milk was dried on pumice stone, this loss would not be expected.

Volatilization.—If the fat had been volatilized, there should be a corresponding loss of dry matter and this would be observed equally in the samples dried in hydrogen and in those dried in air. That there is no loss of dry matter in the majority of cases would seem to rule out the possibility of volatilization unless, indeed, it were accompanied by a compensating oxidation. This hypothesis would fulfill the conditions at present shown to exist, since, when the samples were dried in hydrogen, there was a loss of fat and dry matter; when dried in air there was a loss of fat and no loss of dry matter. Furthermore, in the samples in which there was no vegetable fat to be volatilized, i. e., those in which extracted flour was used, there was a gain of dry matter when dried in air and none when dried in hydrogen.

Occlusion.—Occlusion was suggested by our work of last year, when the dry matter was recovered in almost every case. Occlusion would insure the fat being estimated as carbohydrates without alteration in the amounts of dry matter.

TESTS WITH FLOUR FROM WHICH THE GLIADIN WAS EXTRACTED.

Experiments were therefore undertaken similar to those reported by Snyder (see p. 23) to try the effect of making bread with flour from which the gliadin or plant gelatin had been extracted, since this is the material which binds the flour particles together to form a dough, and when dried might be reasonably expected to cause occlusion. A portion of the same flour used in the previous experiments was digested repeatedly with alcohol and finally with ether. With the flour thus prepared experiments similar to those with the untreated flour were made: (1) The ingredients of bread were mixed and dried without further manipulation. (2) The ingredients were mixed and made into bread, chemicals being used for leavening. (3) Bread was made from the same ingredients with the addition of milk. The results obtained from the analysis of the materials and the resulting products are shown in the following table:

Results of experiments with flour from which the gliadin was extracted.

Experiment No.		Dry matter.	In dry matter.	
			Protein.	Ether extract.
	Flour (100 grams) extracted with alcohol:	*Grams.*	*Grams.*	*Grams.*
29	Flour undried	86.70	7.44	0.44
30	Flour dried in air at 70° C	87.49	7.31	.39
31	Flour dried in air at 100° C	87.86	7.31	.32
	Bread made from flour (100 grams) extracted with alcohol:			
	Flour	86.70	7.44	.44
	Leavening chemicals	3.12		
	Total	89.82	7.44	.44
32	Flour made into dough and dried at 70° C	91.15	7.31	.18
33	Dough dried in air at 100° C	90.75	7.38	.09
34	Dough dried in hydrogen at 100° C	89.22	7.63	.07
35	Bread baked and dried at 70° C	88.00	7.25	.06
36	Bread baked and dried in hydrogen at 100° C	88.71	7.50	.06
	Bread made with extracted flour and milk:			
	Flour extracted with alcohol (100 grams)	86.70	7.44	.44
	Milk (104 grams)	12.70	3.32	3.73
	Leavening chemicals	3.12		
	Total	102.52	10.76	4.17
37	Flour made into dough and dried in air at 70° C	103.07	10.63	3.46
38	Dough dried in air at 100° C	103.27	10.50	2.81
39	Dough dried in hydrogen	102.52	10.63	1.95
40	Bread baked and dried at 70° C	103.03	10.44	2.28
41	Bread baked and dried in hydrogen at 100° C	103.32	10.69	2.31

It was found that the dough made from the extracted flour was like that described by Snyder (see p. 23). It was not sticky and resembled putty in feeling and appearance. The leavening employed caused the mass to expand a little when first placed in the oven; then the top of the loaf began to break apart, and the loaf decreased in size as if no leavening had been used. The loaf when baked was about as heavy as the same bulk of rubber. The results of the experiments show that the fat was not recovered, even when gliadin was absent; that is, removing the gliadin, i. e., the material which it might be assumed would cause an occlusion of fat, did not prevent an apparent loss of fat in bread making.

COMPARISON OF DIFFERENT METHODS OF EXTRACTING FAT.

Several years ago Weibull[1] studied the determination of the fat in bread. He found that bread apparently contained less fat than the

[1] Svensk Kemisk Tidskrift, 1892, No. 5 (Experiment Station Record, 5, p. 520).

flour from which it was made. This he attributed to an error of analysis, since direct extraction with ether gave too low results in the case of bread, no matter how long the extraction was continued. The starch and dextrin of the bread were thought to inclose the fat and prevent the action of the ether. To obviate this difficulty the author proceeded as follows:

From 1 to 3 grams of dry pulverized bread was boiled for an hour with 15 to 20 cubic centimeters of water and 10 drops of dilute H_2SO_4, being stirred occasionally with a glass rod. The solution was then completely neutralized with an excess of calcium carbonate (powdered marble) containing no ether extract and the thick solution transferred to a piece of fat-free filter paper, such as is used in milk analysis, the beaker which had contained the solution being wiped out with absorbent cotton. The paper and cotton were heated at 100° C. for two or three hours, and then extracted in an extraction apparatus with anhydrous ether for ten hours. Parallel determinations by this method agreed perfectly, and comparative analyses of fat in flour and in the bread made from the same according to the author gave concordant results; that is, when a method was employed which prevented the occlusion of the fat it was all recovered.

In view of these results a few samples of flour and bread were treated according to Weibull's method. The results are given in the following table. For purposes of comparison the results obtained by the usual method, and also by direct extraction of the undried substance, are also included since it has been suggested that, when the official method is employed, the preliminary drying still further hardens the particles and increases the occlusion. The results in every case have been calculated to show the grams of fat in 100 grams of flour or the bread made from this quantity.

Comparison of different methods of estimating fat in flour and bread.

Experiment No.		Weibull's method.	Official method.	Direct extraction.[1]
		Grams.	*Grams.*	*Grams.*
1	Flour undried	1.06	1.27	1.44
2	Flour dried in air at 70° C	1.01	1.27	1.30
3	Flour dried in air at 100° C	.71	.84	.94
4	Flour made into dough and dried in air at 70° C	.69	.63	.66
5	Bread baked and dried at 70° C	.66	.28	.37
19	Bread[2] dried in air at 70° C	3.81	3.95	3.73
20	Bread[2] dried in air at 100° C	3.88	3.42	3.73
21	Bread[2] dried in hydrogen	3.82	2.76	3.73

[1] Without further drying of the substance. [2] Made with milk.

Weibull's method gave fairly concordant results, but they were on the whole not as satisfactory as his statements would seem to indicate might be expected.

An examination of the above figures shows no gain in ether extract in the results of experiments with the flour alone. In those cases in which milk was added to the flour in making bread, an amount of fat equal to all the milk fat and a very little more was recovered by Weibull's method, which would indicate that not only was a little of the vegetable fat occluded, but considerable amounts of the animal fat also. This would be more in accord with the results secured from the experiments with milk dried on pumice than would the supposition that oxidation had taken place.

These results and those previously reported (pp. 43, 44) represent experiments on the loss of fat in materials which were heated and, with the exception of the few samples dried, as received, at 100° C. in air, the loss in materials which were wet or made into a dough and dried.

COMPARISON OF EXPERIMENTAL METHODS.

In order to learn how much of the effects were due to heat, a number of tests were made in which the dough was not heated in drying. Portions of flour were made into dough with an abundance of the leavening chemicals to facilitate drying, rolled out thin on plates, and dried at room temperature under bell jars over concentrated sulphuric acid. Two tests were made, the same quantities of flour and leavening materials being used in each case. When analyzed by the official methods the dry matter was found to be lower than the calculated amount, and the ether extract also showed a deficiency as in the previous experiments. The results of the two tests were as follows:

Constituents of materials and dried dough made from them.

Experiment No.		Dry matter.	In dry matter. Protein.	Ether extract.	Carbohydrates.	Ash.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
	Flour (100 grams)	87.80	13.88	1.27	72.14	0.51
	Leavening chemicals	6.24				6.24
	Total	94.04	13.88	1.27	72.14	6.75
42	Dried dough	93.08	13.90	.80	71.63	6.75
43	do	92.72	13.46	.67	71.84	6.75

It will be seen that even in these cases there was a loss of ether extract and dry matter. It should be remembered, however, that even in this instance the determination of dry matter involves drying (in hydrogen) and that the ether extract was regularly determined in this dried portion. Therefore other portions of the flour and dried dough were extracted without previous drying. The results showed but a trifling gain. These experiments, however, showed what is regarded as the cause of the loss of fat, for when the ether extract was dried preparatory to weighing, copious white acrid fumes issued from the flask and constant weight was with difficulty secured. These fumes were not noticed in drying the extract from the substance previously dried, and only slight amounts were noticed in the tests reported on page 47. This would indicate that when samples are analyzed in the ordinary way, the volatilization of a portion of the ether extract probably takes place in drying the sample for analysis, and doubtless also occurs whenever the sample is dried or baked. If this is the case, the samples prepared in the early experiments should show a loss of substance, and if this is compensated by a corresponding oxidation it should be possible to detect the loss by means of the calorimeter. On the other hand, in experiments Nos. 42 and 43 the heat of combustion of the substance as it comes from the desiccator should be the same as that of the material before drying; i. e., there should be no loss in energy, the analytical results to the contrary notwithstanding. Such determinations were made, therefore, upon these samples (Nos. 42 and 43), and a number of others and the results obtained, together with the amounts of dry matter and ether extract in the samples, are given in the following table:

Dry matter, ether extract, and heat of combustion of flour and bread treated in various ways.

Experiment No.		Dry matter.	Ether extract in dry matter.	Heat of combustion.
	Unextracted flour (100 grams).	*Grams.*	*Grams.*	*Calories.*
	Mixture of flour (100 grams) and leavening chemicals (1.56 grams)	89.36	1.27	387.37
8	Same mixture dried in air at 70° C	89.71	1.23	377.07
9	Same mixture dried in air at 100° C	89.41	.55	378.08
12	Dough dried in hydrogen	89.04	.32	381.85
13	......do	89.01	.31	380.79
	Mixture of flour dried in desiccator and leavening chemicals (6.24 grams)	94.04	1.27	387.37
42	Dough from same	93.08	.80	389.61
43	......do	92.72	.67	387.27
	Flour extracted with alcohol (100 grams).			
29	Flour undried	86.70	.44	371.63
30	Flour dried in air at 70° C	87.49	.39	367.80
31	Flour dried in air at 100° C	87.86	.32	366.65
	Mixture of flour (100 grams) and leavening chemicals (3.12 grams)	89.82	.44	371.63
34	Dough from same dried in hydrogen	89.22	.07	371.15

Although these results were obtained from a limited number of samples, they have been made in duplicate and in some cases in triplicate and were found to be concordant, indicating that they are trustworthy. They show exactly that which was expected from the preceding work. The material dried over sulphuric acid has lost none of its potential energy and, therefore, presumably none of its substance previous to drying in hydrogen; the whole flour when dried in hydrogen lost both potential energy and substance, which, since the possibility of oxidation was excluded, must be due to volatilization; when dried in air the material lost still more fuel value, but showed no loss of substance. Both of these facts can be explained by absorption of oxygen, i. e., slow combustion or oxidation. When the material contained no vegetable fat to volatilize, there was no loss of substance or of energy when dried in hydrogen. Furthermore, there was a gain of weight and loss of energy when dried in air.

CONCLUSIONS.

From these results it seems proper to conclude that at high temperatures there is a partial volatilization of the vegetable fat in bread making, especially in the presence of escaping water vapor, and, in addition, an oxidation of the residual organic matter. When animal fat was added to the dough there seemed to be an occlusion of fat, probably due to the formation of dextrin. The application of this theory to the results of the bakery experiments previously referred to explains the facts noted, namely, that—

(1) Although yeast was used in all the bakery experiments and the destruction of carbohydrates must have been considerable, yet the experiments at New Brunswick, unlike that at Pittsburg, show no apparent loss of carbohydrates.

(2) The fuel value when calculated by the usual factors[1] was less than the value obtained by actual determinations in the second New Brunswick experiment, while this was not the case in the experiment made at Pittsburg.

(3) The loss of fat in the New Brunswick experiments, when animal fat (in milk) was added in making the bread, was proportionately less than in the Pittsburg experiment.

The loss of carbohydrates is partly covered in the Pittsburg experiment, where no animal fat was used, by an oxidation of organic matter, and in the New Brunswick experiment, where animal fat was used, by oxidation of the same character, together with an occlusion of some of this animal fat. By the usual methods of analysis this would be calculated as carbohydrates. Therefore, in the application of estimated fuel values to the lost nutrients in the New Brunswick experiment 9.3 calories per gram is too large a value for loss of fat, since a portion of the fat is not lost, but is occluded and thereby estimated as carbohydrates. On the other hand, 4.1 calories per gram (the value for carbohydrates) is too small, since the entire amount of fat is not occluded, there being some absolute loss of fat and in addition a partial oxidation of organic matter. The carbohydrates so called, thus gain in weight but lose fuel value. In the Pittsburg experiment no animal fat was used in making the bread. If it be assumed that no occlusion of fat took place, the use of the customary factors in calculating the fuel

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[1] On the supposition that 1 gram of protein, fat, and carbohydrates will yield 5.5, 9.3, and 4.1 calories, respectively, in the estimation of fuel values as distinguished from heats of combustion the factor 4.1 per gram is commonly used for protein compounds, thus allowing for their incomplete oxidation in the body.

The factors for determining the fuel value of cereals and cereal products have been recently investigated by the Division of Chemistry of this Department (U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1243). On the basis of determinations of the heat of combustion of the different constituents of cereals (with the exception of proteids) factors are proposed which differ somewhat from those mentioned above.

values would give a result a trifle too small, on account of the slow oxidation referred to. This was in accord with the observed facts.

From the investigations reported in this bulletin it is evident that some of the apparent loss of ether extract in bread making was due to heat employed in baking the bread and to the heat employed in drying the samples for analysis.

When samples of flour, dough, and bread were dried in air or in hydrogen previous to analysis, an apparent loss of ether extract was observed. It should be remembered, however, that since ether extract is usually determined in a sample used for determination of dry matter, the materials have been subjected to two dryings, one previous to analysis and one during analysis. When samples of flour and dough dried over sulphuric acid were analyzed there was also an apparent loss of fat. The loss was, however, smaller than was the case when samples dried in air or hydrogen were analyzed. In this case the samples had been submitted to the action of heat but once; that is, in the determination of dry matter in the sample before extracting with ether. Samples of dough dried over sulphuric acid were extracted with ether without any further drying; that is, without submitting them to the action of heat. In this case slightly more ether extract was recovered than when similar samples were extracted after drying in an oven for the determination of dry matter. In all these cases, however, there was an apparent loss of ether extract; that is, when flour is made into dough and dried or baked, all the ether extract of the flour can not be recovered. It would appear from the data reported that the losses which have been observed in previous investigations at New Brunswick and Pittsburg were more largely due to the analytical methods, that is, to the drying to which the samples were submitted than to the action of the heat in baking. This is not surprising, since baking the bread occupied but twenty or thirty minutes, while the drying for analysis required five or six hours; furthermore, the temperature of the bulk of the loaf during baking was not greater than that of the sample when dried in hydrogen. There was more of the pleasant odor of bread making when the samples were drying than when they were baking. In all cases when the drying was made in hydrogen the sulphuric acid in the trap at the exit of the hydrogen current became black, indicating that some volatile compound was absorbed by it and oxidized. The results obtained indicate that less oxidation of fat takes place at 70° than at 100°, therefore the former temperature is to be preferred in drying organic materials for the estimation of dry matter.

These considerations indicate that the usual custom of drying fodder and food samples in air or in hydrogen in a drying oven previous to extraction with ether should be carefully investigated in view of the possible errors in the estimation of ether extract involved.